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ABSTRACT

Side-developments of an instructional systems development team which are themselves important products of a research effort are documented in this report. The five studies presented include an investigation of the comparability of computer-assisted and conventional test administration, prompting and confirmation as instructional strategies with computer-assisted instruction, analysis of student performance records, a survey of computer scinece literature relevant to computer-assisted instruction, and a computer-assisted approach to spelling. (EM 011 038 through EM 011 043, EM 011 046, EM 011 047, and EM 011 049 through EM 011 058 are related documents). (SH)

C·A·I

COMPUTER ASSISTED INSTRUCTION LABORATORY

COLLEGE OF EDUCATION · CHAMBERS BUILDING

THE PENNSYLVANIA STATE UNIVERSITY · UNIVERSITY PARK, PA.

EXPERIMENTATION WITH COMPUTER-ASSISTED INSTRUCTION IN TECHNICAL EDUCATION

SEMI-ANNUAL PROGRESS REPORT

DECEMBER 31, 1968

Report No. R-18

Note to accompany the Penn State Documents.

In order to move the entire collection of reports generated by the Computer Assisted Instruction Lab. at Penn State University (not now in the ERIC archives), the ERIC Clearinghouse on Educational Media and Technology was asked by Penn State to input the material. We are therefore including some documents which may be several years old. Also, so that our bibliographic information will conform with Penn State's, we have occasionally changed the title somewhat, or added information that may not be on the title page. Two of the documents in the CARE (Computer Assisted Remedial Education) collection were transferred to ERIC/EC to abstract. They are Report Number R-36 and Report Number R-37.

Jacklyn Caselli; ERIC/EM

The Pennsylvania State University

Computer Assisted Instruction Laboratory
University Park, Pennsylvania

Semi-Annual Progress Report

EXPERIMENTATION WITH COMPUTER-ASSISTED INSTRUCTION IN TECHNICAL EDUCATION

Project No. 5-85-074

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FOREWORD

An active instructional systems development team will often take on a specific mission to fulfill the objectives of a grant. Enroute to that goal some members of the team inevitability follow serendipitous leads which result in exploration of many new and exciting ideas. This semi-annual report although delayed for valid reasons, provides documentation on some of these less planned, but nevertheless important products of a major research effort.

In the management of the present grant from the U. S. Office of Education it has been our practice to encourage talented staff members to follow some new and interesting leads of their own choosing. We think the results of these explorations provide grist for the development of future proposals and should be shared with the community of scholars interested in computer applications to instruction.

Harold E. Mitzel
University Park, Pa.
June 11, 1971

CONTENTS

COMPARABILITY OF COMPUTER-ASSISTED AND CONVENTIONAL TEST ADMINISTRATION

Robert B. King and William Rabinowitz

Studies dealing with learner variables under computer-assisted instruction (CAI) frequently require the use of standardized performance measures. It may be desirable to precede CAI programs with standardized aptitude tests to select the appropriate level and type of instruction for each individual, and achievement tests are almost always needed at the end of instructional sequences to measure proficiency and diagnose learner difficulties. Although such tests may be administered by traditional methods, there are certain advantages in having the computer conduct the administration. Apart from the more obvious benefits of rapid scoring and diagnostic decision making, computerized test administration has a natural appeal in view of the computer's ability to control many troublesome test administration variables. Greater uniformity across administrations can be achieved by controling item exposure time and item sequence, and recent evidence (Heckman, Tiffin, and Snow, 1967) indicates that item exposure control will increase internal consistency without affecting other test characteristics adversely.

Caution is warranted, however, in assuming that computer-administered test results are comparable to those from conventional administration. Certain aspects of the computer testing environment such as the absence of an examiner, the presence of complicated interface equipment, and the isolation of the student are unique to computerized administration and constitute potential contributors to test variance. If these aspects produce sizable components of reliable variance, normative data based on conventional administration may be misleading.

A number of researchers (Hopkins, Lefever, and Hopkins, 1967; Fargo, et al., 1967; Heckman, et al., 1967; Curtis and Kropp, 1961a, 1961b; Burr, 1963) have investigated the comparability of printed versus televised or visual-slide-projected test administration. Their results, in general, indicate no substantial differences among these presentation media in terms of item and test characteristics. Televised and slide-projected administration are group modes, however, and use conventional printed response forms. Thus generalization cannot be made to computer administration where the student responds via

machine in a relatively isolated setting. Also, the above studies used achievement and intelligence tests for comparison - measures not particularly sensitive to variation in the test conditions. O'Bryan and Boersma (1968) recently demonstrated that test presentation variations that have little effect on verbal and nonverbal intelligence scores can produce considerable differences in measures such as creativity. Thus, if computer administration introduces new sources of variance not found in conventional testing modes, the effect would probably be most likely to occur in measures of creativity. The purpose of the research reported here, therefore, was to compare conventional group administration and computer-assisted administration of a test of creativity.

Method

Two separate studies were conducted using different Ss and slightly different procedures. They used the same basic measures and analysis, however, and thus may conveniently be presented together. Study I was a preliminary effort to the larger, more extensive Study II.

Subjects

Study I used 37 paid volunteer male technical education (two-year program) students enrolled at The Pennsylvania State University Random assignment was made to either a computer-assisted or a conventional test administration condition. Study II used 107 (36 male, 71 female) volunteer undergraduates enrolled in baccalaureate programs at The Pennsylvania State University. Ss within each sex were randomly assigned to the two test conditions to insure equal proportions of males and females under each condition.

Procedures and Equipment

The primary measuring instrument selected for both studies was Form 1 of the Remote Associates Test (RAT, Mednick and Mednick, 1967). The RAT is a verbal test of creativity consisting of 30 items, each requiring a single verbal response. Each item consists of three words and the Ss has to arrive at the appropriate response to these words through associative processes. An

example is the three words rat, blue, and cottage. The S is required to find a fourth word which serves as a remote associative link to each of these words. Cheese is the correct answer in this case.

In the computer-assisted test condition, the RAT Form 1 was converted for computer use with the Coursewriter CAI language. Test instructions under the computer-assisted condition paralleled the standard printed form as nearly as possible. The 30 items of the RAT were placed on 2 x 2 inch slides, and presented via random access slide projectors operated in conjunction with four IBM 1050 typewriter terminals. All four terminals were connected to an IBM 1410 computer located on the main campus. The computer version of the test was untimed, and item progression was controlled by S. As each item was presented, Ss would either type an answer or choose to skip the item. No time limits were imposed for items, but response latencies were recorded by the computer, and Ss were urged to answer more rapidly or consider skipping items when latencies on preceeding items exceeded three minutes. All items skipped were recycled and presented in sequence a second, and if necessary, a third time. S receiving an unanswered item for the third time were instructed to guess at the item if they were still unable to decide upon an answer. Tests administered under this condition were scored on the basis of total number of items correct, and specific items missed were recorded on the print-out. All scoring was done by the computer which was programed to accept a variety of spelling options for each correct answer.

Ss recieving the RAT Form 1 under the conventional administration condition were given the standard printed test forms in the presence of an examiner. Administration followed the procedures specified in the RAT Examiner's Manual, with the exception that the tests were untimed instead of adhering to the 40-minute time limit recommended in the manual. Since only four students could be tested simultaneously under the computer-assisted condition, Ss assigned to the conventional condition were tested in small groups of approximately four each at times corresponding to the computer assisted testing session. Test administration for both groups took place over a five-day interval.

All procedures involving the administration of RAT Form 1 under both conditions were identical for Studies I and II. Study II differed from Study I, in that after Ss in both administration conditions had completed RAT Form 1,

they received four additional reference tests administered at one central location using conventional procedures. The four reference measures were the RAT Form 2, an unstandardized verbal fluency measure called Anagram Frequency by the investigators, a scoring variation of the Anagram Frequency measure called Anagram Originality, and an unstandardized paper and pencil opinion scale called Flexibility Inventory.

The first three reference measures were selected because they were easily administered paper and pencil measures known to correlate with the RAT Form 1. The RAT Form 2 is not quite as reliable as Form 1, but Mednick and Mednick (1967) report that the two forms correlate to the extent of .81. The two anagram measures were employed by Higgins (1966) in an investigation of correlates of the RAT Form 1, and are reported by Mednick and Mednick (1967) as part of the construct validity evidence supporting the RAT. Higgins asked Ss to construct as many words as possible, of four or more letters, from the word "generation." Scores were given for the total number of words and the originality of words (defined as words given by no more than two other Ss.) The frequency measure correlated .31 with RAT scores, and the originality measure correlated .43.

The fourth criterion measure was a forced-choice opinion inventory developed by the second author and believed to measure a dimension best described as "flexibility of thinking." It was employed in the present study to detect possible interactions between administration mode, creativity, and a potentially related attitudinal measure.

Analysis

The problem of determining whether computer-assisted testing and conventional testing are directly comparable is really a problem of determining the equivalence of two forms of the same test--one administered by computer and the other by conventional procedures.

Medley (1957) has proposed a procedure for testing the equivalence of two tests which examines four criteria: equality of means, equality of variances, equality of errors of measurement, and "homogeniety of function." The procedure is based upon a two-factor analysis of variance with repeated measures on one factor, and is especially appropriate for use in studies of

the type reported here where carry-over effects necessitate the use of different subjects for the two test forms (or in this case two modes of administration).

In the present experiment, the Medley test for equivalence was applied in both Study I and Study II to compare the performance of the computer-assisted and conventional groups on the RAT Form I. The two administration modes coupled with the 30 items of the RAT resulted in a 2 X 30 factorial design, with repeated measures across subject. In the Medley procedure each of the four criteria for equivalence (equal means, equal variances, equal errors of measurement, and homogeniety of function) can be stated as a null hypothesis, and if any are rejected the tests in question cannot be regarded as equivalent. If all four null hypothesis cannot be rejected then the overall hypothesis of equivalence may be accepted. The four F-ratios corresponding to the four hypothesis were calculated and tested for significance in both studies.

Additional correlational analyses were performed in Study II to determine the existance of possible differential relationships between the two administration modes of the RAT Form 1 and the four reference measures. Pearson product-moment correlation coefficients were calculated between each of the reference measures and each mode of administration of the RAT Form 1, and all pairs within administrations were tested for significant differences with z-transformations.

Results

Table 1 presents the descriptive statistics for the two administration modes of the RAT Form 1 under both studies. The means and standard deviations for all administrations compare favorably with those reported by Mednick and Mednick (1967) in the normative data for college undergraduates. Hoyt internal consistency reliability estimates, calculated from the analysis of variance format used for the Medley procedure, were found to be slightly lower than odd-even split-half coefficients reported by Mednick and Mednick.

One noteworthy comparison that can be made from Table 1 is the high degree of similarity between the performance of the technical education Ss in Study I and the baccalaureate program Ss in Study II. Students enrolled in two-year

Table 1

RAT Form 1 Statistics for Studies I and II

	Study I 2-year Tech. Education Students		Study II 4-year Baccalaureate Students	
	CAI	Conv.	CAI	Conv.
M	14.53	15.39	15.28	16.50
SD	4.58	5.33	5.65	5.10
N	19	18	53	54
Hoyt Reliability	.74	.81	.84	.78

technical education programs are generally believed to be less intellectually capable than four-year students. Although many variables were uncontrolled between Studies I and II the results would appear to indicate that in at least one dimension of intellectual functioning the two-year students compare quite closely with four-year students.

Results of the Medley equivalence analysis are summarized in Table 2. Calculation of the *F*-ratios used to test each of the four equivalence criteria necessitated dividing the overall analysis of variance into separate analyses representating each mode of administration, and an analysis representing the combined administrations. The first criterion of interest, equality of means for the two administration modes, was tested by comparing the variance between administrations with the variance for *Ss* within administrations. The resulting *F*-ratios for both studies were nonsignificant, indicating failure to detect differences with respect to the mean performances under the two modes of administration. The second criterion, equality of variances, was tested by forming an *F*-ratio from the mean square for subjects in each of the separate mode analyses. Again, the *F*-ratios for both studies were nonsignificant, and the conclusion is that the variances for the two modes of administration are

not reliably different. The third criterion, equality of measurement error variances, was tested by an F-ratio formed from the error terms in each of the separate mode analyses. Here a significant F was obtained for Study II, but since the value of the F was only 1.06 with 1537 and 1508 df the difference is probably not of great consequence. Thus, the criterions of equal measurement variances also appears to be reasonably satisfied. The final criterion, homogeniety of function, was tested with an F-ratio formed by comparing the error between administrations with the error within administrations. A significant F was obtained for Study II indicating that the item difficulty rankings were not the same for both modes of administration. Items proving very difficult under computer administration were apparently slightly easier under conventional administration and vice versa. The resulting conclusion is that in Study II the RAT Form 1 was not measuring identical functions under the two modes of administration.

Table 3 presents the results of the additional correlational analyses performed in Study II. The correlations between each of the administrations of the RAT Form 1 and each of the reference measures correspond (in the case of the first three reference measures) roughly with those reported by Mednick and Mednick (1967). The correlations between the RAT Form 1 and the RAT Form 2 are slightly lower than reported in the Test Manual. The fourth reference measure, Flexibility, does not appear to correlate with the RAT. All four correlation pairs between administration modes were tested for significance, and none of the differences proved significant. Thus, there is no evidence to indicate that the parallel forms reliability or the validity of the RAT are any different under computer administration than under conventional administration.

Discussion

Medley (1957) indicates that rejection of any of the four hypothesis forming the criteria of equivalent tests constitutes sufficient justification for rejection of the overall hypothesis of equivalence. Strict adherence to that policy in the present investigation would lead to the conclusion that, at least for verbal measures of creativity like the RAT Form 1, computer-assisted test administration is not the same as conventional group administration. The following considerations, however, are relevant:

Table 3

Correlations of RAT Form 1 and Reference Measures (Study II)

Mode of Administration RAT Form 1	Reference Measures			
	RAT Form 2	Anagram Frequency	Anagram Originality	Flexibility Inventory
Conventional	.55	.49	.38	.11
CAI	.66	.41	.34	-.13

Note.--All differences were tested for significance using the z-transformation. None attained significance at the .05 level. Although the individual correlations are not marked for significance, a correlation of .269 (df = 52) is required for significance under the conventional administration and a correlation of .286 (df = 46) is required under the CAI administration. Correlations equal to or exceeding these values constitute significant departures from zero at the .05 level.

1) Statistical significance does not, of course, mean practical significance. Although none of the hypotheses was rejected in Study I, the test for homogeniety of function and equality of measurement errors did indicate statistically significant differences between modes of administration in Study II. The differences appear to be slight, however, and probably of little practical significance.

2) The correlational analyses performed in Study II indicate once again that differences between modes of administration, if present, are indeed slight.

3) Since homogeniety of function was not significant in Study I where technical education students were used as Ss the effect, even if present among four-year baccalaureate degree students, cannot be generalized across different ability levels or to different classes of students.

4) Finally, it is important to consider that creativity was specifically selected as the measurement variable in this investigation because of its known sensitivity to variations in the testing environment. Thus, even the most conservative interpretation of the present findings would not warrant generalization to the testing of other mental abilities.

In summary, the study reported here does not present any evidence to indicate that computer-assisted test administration introduces new sources of variance that markedly modify the statistical properties of a test as determined through conventional administration.

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PROMPTING AND CONFIRMATION AS INSTRUCTIONAL STRATEGIES WITH COMPUTER ASSISTED INSTRUCTION EXPERIMENT 1

Keith A. Hall and Karl G. Borman

Cook and Spitzer (1960) and Stolurow and Lippert (1962) among other investigators have found strong differences between confirmation and prompting procedures in learning. The data indicate that prompting enables the student to achieve criterion level much more rapidly than does a confirmation mode. However, confirmation appears to provide better retention than does prompting at differing levels of overlearning, Stolurow and Lippert (1962). It is important to note, however, that neither of these studies were done in an environment which could be broadly applied in education--the Cook and Spitzer study was a very closely controlled laboratory study and the Stolurow and Lippert study was done using flash cards with mentally retarded children. Computer-assisted instruction seems to provide a measure of control somewhere between a hand-administered treatment and a closely controlled laboratory-administered treatment. One important consideration is that the computer-assisted instruction procedures can be replicated and can be utilized by many students in a typical educational setting.

The effects of treatment (prompting or confirmation); criterion level (1, 3, or 6 consecutive correct responses to each stimulus item); intervals between administrations of the retention test (1, 7, or 21 days); and order of treatment (prompting treatment followed by confirmation treatment [P → C] or confirmation treatment followed by prompting treatment [C → P]) on retention test scores; instruction time; and number of responses during instruction were examined in this study.

Method

Materials

Sixteen geometric patterns were selected for use as stimulus items from the American Standard Association drawings for piping layouts on architectural drawings. As can be seen in Figure 1, there were rather marked similarities

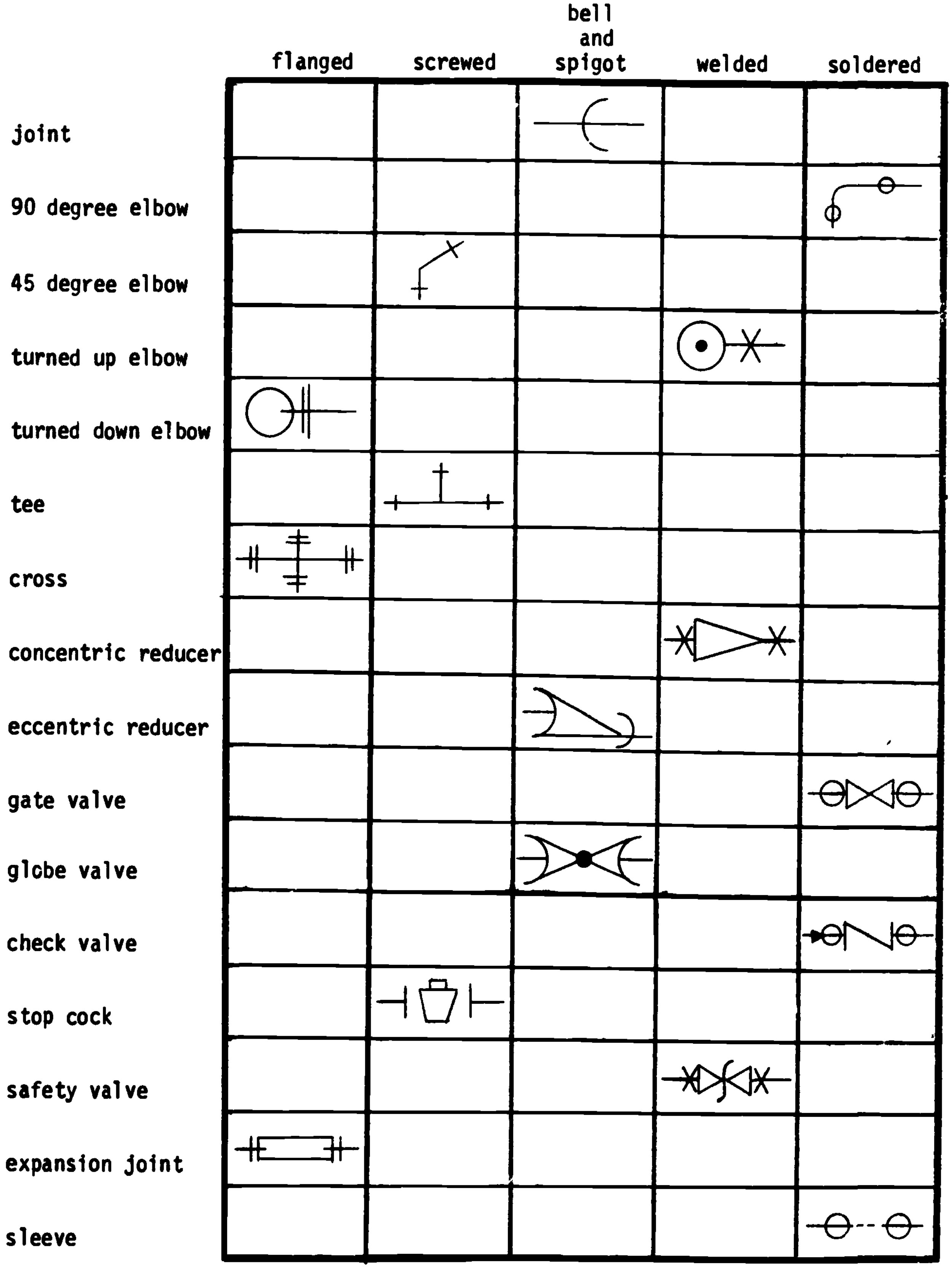

Fig. 1. Stimulus and response item matrix.

not only between items but also between the items and the referents. The stimulus items were presented under computer control to the subject on a small rear-projection screen and the subject responded by typing the name of the item on the typewriter keyboard at a computer terminal. The responses consisted of two elements: 1) the word or phrase which identified the type of fastening and 2) the name of the piping element, e.g., flanged cross, bell and spigot globe valve, and welded safety valve. The prompts and confirmations consisted of the entire response components (1 and 2 above) and were typed at the typewriter terminal by the stored computer program.

Procedures

Subjects in Group P → C learned the first eight items in a prompting mode followed by a second set of eight items in a confirmation mode. Subjects in Group C → P received the first eight items in a confirmation mode followed by a second set of eight items in a prompting mode. The subjects were randomly assigned to Group P → C or C → P and the items were randomly selected for presentation by either prompting or confirmation. Additionally, the items within each of the two lists for each subject were presented in a random order for each subject.

The confirmation mode consisted of presenting the stimulus, followed by the subject's response, which was in turn followed by confirmation consisting of the correct response for the subject to view. This sequence was used for each item in the confirmation mode. In the prompting mode the stimulus was presented followed by the prompt (consisting of the correct response) for the subject to view who then responded by typing that response on the typewriter terminal. These sequences are shown in Figure 2.

On the first three cycles through the eight items in each treatment, the strict prompting or confirmation mode was followed for each subject. At the end of the third cycle a test cycle was employed which presented the stimulus items one at a time to the subject and waited for the subject to respond. In this test sequence, no prompt or confirmation was given to the subject. Each item which was answered correctly in the test cycle remained in a test cycle until the subject reached criterion level (1, 3, or 6 consecutive correct responses) on the item or until he responded incorrectly to the item. When he

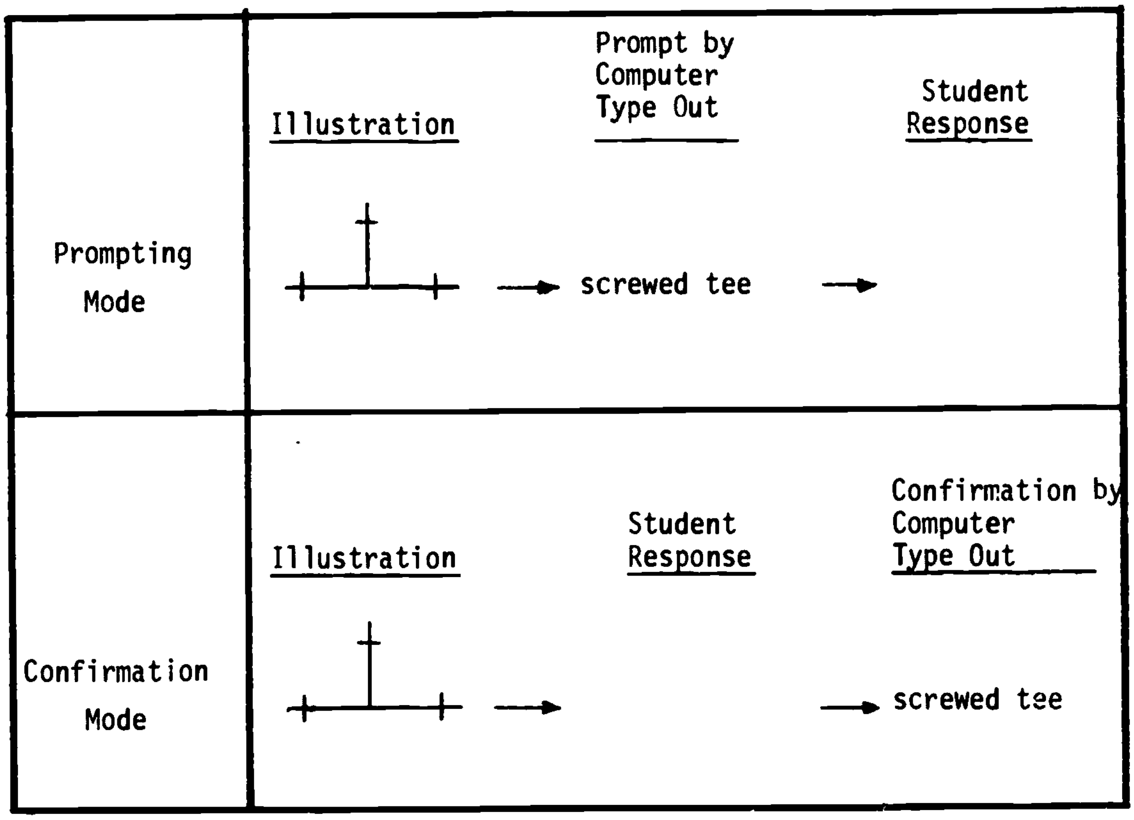

Fig. 2. Sequence of events for each item presented in prompting and confirmation modes.

reached criterion, that item was dropped from the sequence. However, if he responded incorrectly to an item before reaching criterion, that item was returned to the original instructional mode of either prompting or confirmation. Each subject continued through the materials until he had reached his assigned criterion of either 1, 3, or 6 consecutive correct responses in a testing mode for each item. It is important to note that after the first test cycle, some items remained in a test mode and some reverted to the original instructional mode of either prompting or confirmation resulting in a mixed presentation.

Retention tests were administered one, seven, and twenty-one days following the experimental treatment. The retention test consisted of presenting each of the sixteen stimulus items to the subject one at a time and allowing him to respond on the typewriter terminal. No feedback was given at any point in the retention test regarding the success or failure of the subject on the items.

Subjects

Thirty-nine college sophomores and juniors in the College of Education at The Pennsylvania State University with no background in engineering were randomly assigned to the experimental conditions Each subject was paid a fixed fee for participating in the experiment.

Design

A 2 x 3 x 3 design was employed. Each subject was randomly assigned to a treatment order (P → C or C → P) and to a criterion level (1, 3, or 6) and produced data on each of the dependent variables (retention tests at 1, 7, and 21 day intervals, instructional time, and number of responses during instruction.

It was expected that prompting would produce faster learning (less time and fewer responses during instruction) but poorer retention on the materials and that confirmation would produce slower learning (more time and more responses during instruction) of the materials but better retention. It was expected that criterion level (or the amount of over-learning) would interact

significantly with the instructional treatment and retention interval. Further, it was expected that there would be no proactive or retroactive facilitation or inhibition between the modes or sequence of instruction.

Findings

Analyses of variance were performed to determine the effects of the independent variables upon the dependent variables. Table 1 summarizes the analyses of the dependent variables associated with acquisition of the learning task with order considered.

The Effect of Order

Number of responses. The analysis of the number of responses during prompting and confirmation yielded no significant differences. However, the requirement of homogeneity of variance was not met for the number of responses during confirmation. The effect of violating the assumption of homogeneity of variance is unknown and therefore precludes any interpretation of the data.

Instructional time. The analysis of the amount of instructional time during the prompting mode yielded an F-ratio of 4.217 which is significant at the .05 level of confidence (df = 1,33). The mean instructional time during prompting was 37.04 minutes (n = 19) when the prompting items were presented first and 29.44 minutes (n = 20) when the prompting items were presented second. A similar result was obtained from the analysis of instructional time during confirmation although the requirement of homogeneity of variance was not met which again precluded interpretation of the data. The effect that order had on instructional time during prompting and the uncertainty of the data related to the number of responses and the instructional time during confirmation cast doubt on the advisability of pooling all confirmation data and all prompting data and ignoring the effect of order as had orginally been planned. Therefore, the remainder of the analyses were conducted with order of instructional mode considered and kept separate.

Table 1

Analysis of Variance of the Dependent Variables
Associated with Acquisition with Order-of-Treatment Groups
(Prompting Followed by Confirmation and
Confirmation Followed by Prompting)
Considered and Kept Separate

N = 39

	Sources of Variance					
	Order		Criterion Level		Interaction	
Dependent Variables	MS	F(1,33)	MS	F(2,33)	MS	F(2,33)
Number of Responses During Prompting	235.59	1.065	1232.14	5.564**	367.33	1.659
MSe = 221.46						
Amount of Time During Prompting	562.16	4.217*	1822.89	13.675**	349.98	2.625
MSe = 133.30						
Number of Responses During Confirmation***	1136.68	4.150	535.00	1.953	104.47	<1.00
MSe = 273.89						
Amount of Time During Confirmation***	1158.37	7.360**	1674.70	10.641**	3.42	<1.00
MSe = 157.38						

*Significant at the .05 level

**Significant at the .05 level

***Hypothesis of homogeneity of variance was not supported

The Effect of Criterion Level

Number of responses. Criterion level (1, 3, or 6 consecutive correct responses) produced an unexpected progression of number of responses for items learned by prompting (1: $\overline{X}$ = 26.36, n = 14; 3: $\overline{X}$ = 45.10, n = 14; 6: $\overline{X}$ = 34, n = 11) the differences all being significant at the .01 level (F-ratio = 5.564, df = 2,33). The violation of the assumption of homogeneity of variance for the confirmation data precludes the interpretation of these data.

Instruction time. Criterion level (1, 3, or 6 consecutive correct responses) had the anticipated effect of producing a steady increase in instructional time for items learned by prompting (1: $\overline{X}$ = 20.48 minutes, n = 14; 3: $\overline{X}$ = 38.11 minutes, n = 14; 6: $\overline{X}$ = 42.93 minutes, n = 11) and for items learned by confirmation (1: $\overline{X}$ = 22.86 minutes, n = 14; 3: $\overline{X}$ = 37.43 minutes, n = 14; 6: $\overline{X}$ = 45.51 minutes, n = 11). The analysis of the effect of criterion level on the amount of time during prompting mode produced an F-ratio of 13.675 (df = 2,33) which is significant at the .01 level. However, again the violation of the assumption of homogeneity of variance for instructional time for items learned by confirmation suggests some degree of uncertainty in these data.

Interactions

Prompting. Table 2 summarizes the analysis of variance for repeated measures of retention scores for items learned by prompting with order considered. Criterion level (1, 3, or 6 consecutive correct responses) had the anticipated effect on retention with items learned by prompting, i.e., the higher the criterion level the higher the retention scores (1: $\overline{X}$ = 4.45, n = 42; 3: $\overline{X}$ = 4.57, n = 42; 6: $\overline{X}$ = 6.27, n = 33). The differences between 1 and 6 and 3 and 6 consecutive correct responses were significant at the .05 level. Although an analysis of retention scores for items learned by prompting across retention intervals yields an F-ratio of 3.789 which is significant at the .05 level (df = 2,66), it cannot be unambiguously evaluated because of a significant interaction between retention interval and order shown graphically in Figure 3.

Table 2

Analysis of Variance
for Repeated Measures of Retention Scores
for Items Learned by Prompting with Order Considered

Sources of Variance	DF	MS	F-ratio
Between Subjects			
Order	1	13.03	1.447
Criterion	2	36.88	4.096*
Order x Criterion	2	5.21	<1.00
Error	33	9.00	
Within Subjects			
Retention Interval	2	6.01	3.789*
Order x Retention	2	5.15	3.249*
Criterion x Retention	4	1.66	1.045
Order x Criterion x Retention	4	.26	<1.00
Error	66	1.59	

*Significant at the .05 level

Confirmation. The analysis of variance for repeated measures of retention scores for items learned by confirmation with order considered is summarized in Table 3. The analysis of scores across retention intervals during the confirmation mode yielded an F-ratio of 10.138 which is significant at the .01 level of confidence (df = 2,66). This cannot be evaluated properly because of the interaction with order shown graphically in Figure 4.

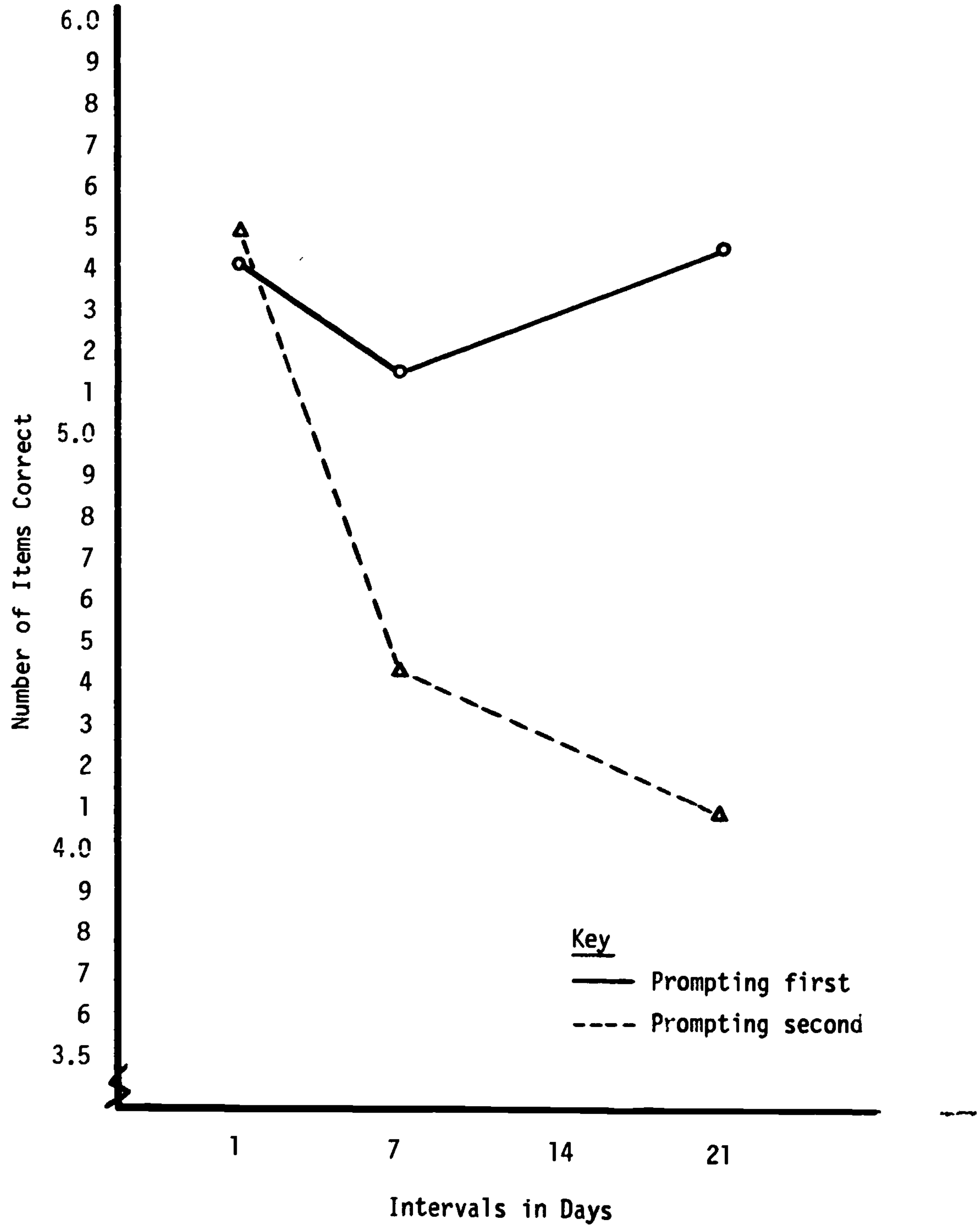

Fig. 3. Interaction between retention interval and order for items learned by prompting.

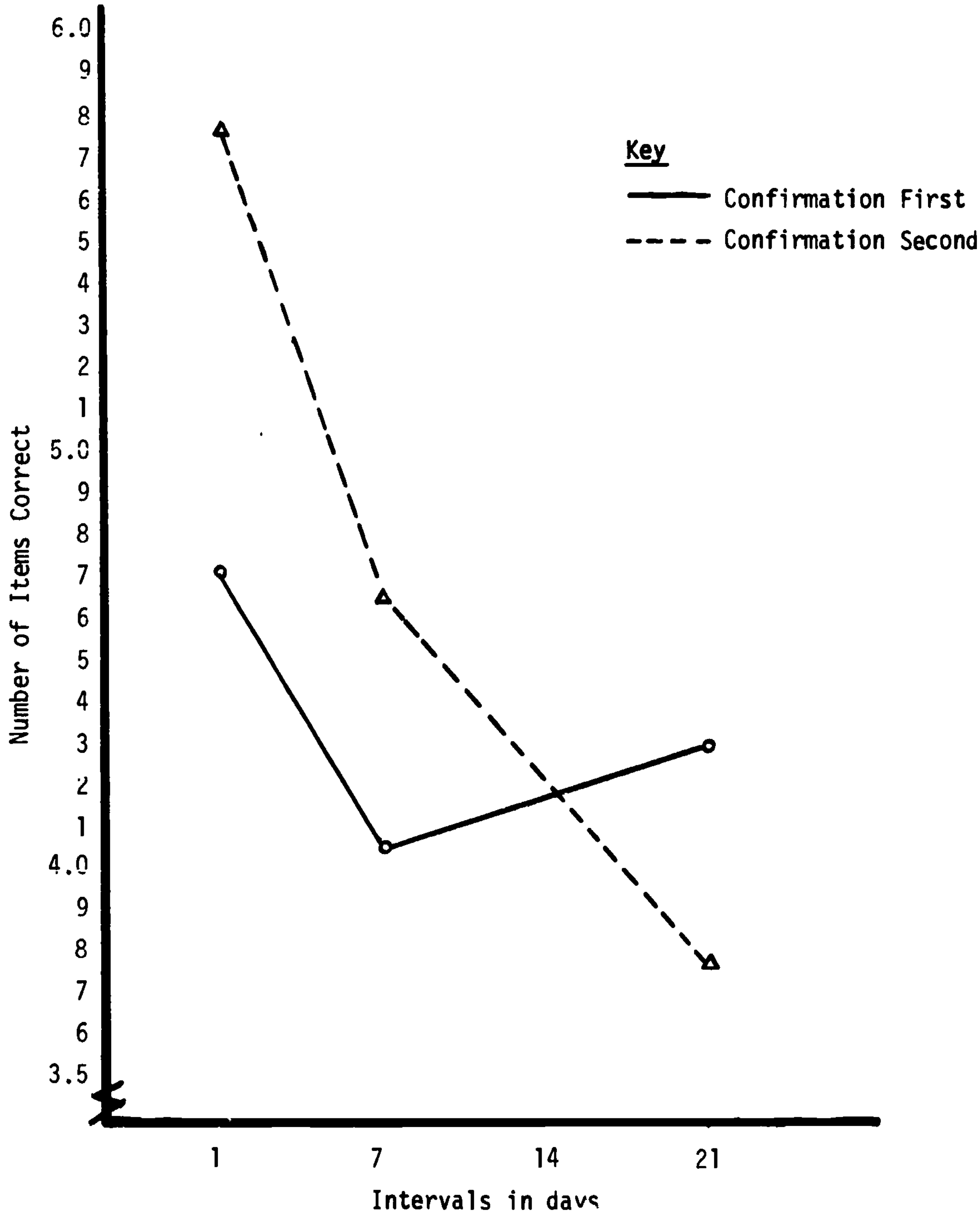

Fig. 4. Retention intervals in days.

Table 3

Analysis of Variance
for Repeated Measures of Retention Scores
for Items Learned by Confirmation with Order Considered

Sources of Variance	DF	MS	F-ratio
Between Subjects			
Order	1	3.83	<1.00
Criterion	2	27.95	2.844
Order x Criterion	2	9.08	<1.00
Error	33	9.83	
Within Subjects			
Retention Interval	2	14.03	10.138**
Order x Retention	2	6.18	4.471*
Criterion x Retention	4	.62	<1.00
Order x Retention x Criterion	4	.11	<1.00
Error	66	1.38	

*Significant at the .05 level

**Significant at the .01 level

Conclusions

The data indicate that prompting is the better procedure to use for the initial learning. S's who learned by prompting first required less time to reach criterion and also maintained better retention as is shown graphically in Figure 5.

The data produced by the confirmation treatment indicate that some prior experience with the materials to be learned was helpful. Confirmation did not provide the strong results that were expected on the retention tests although

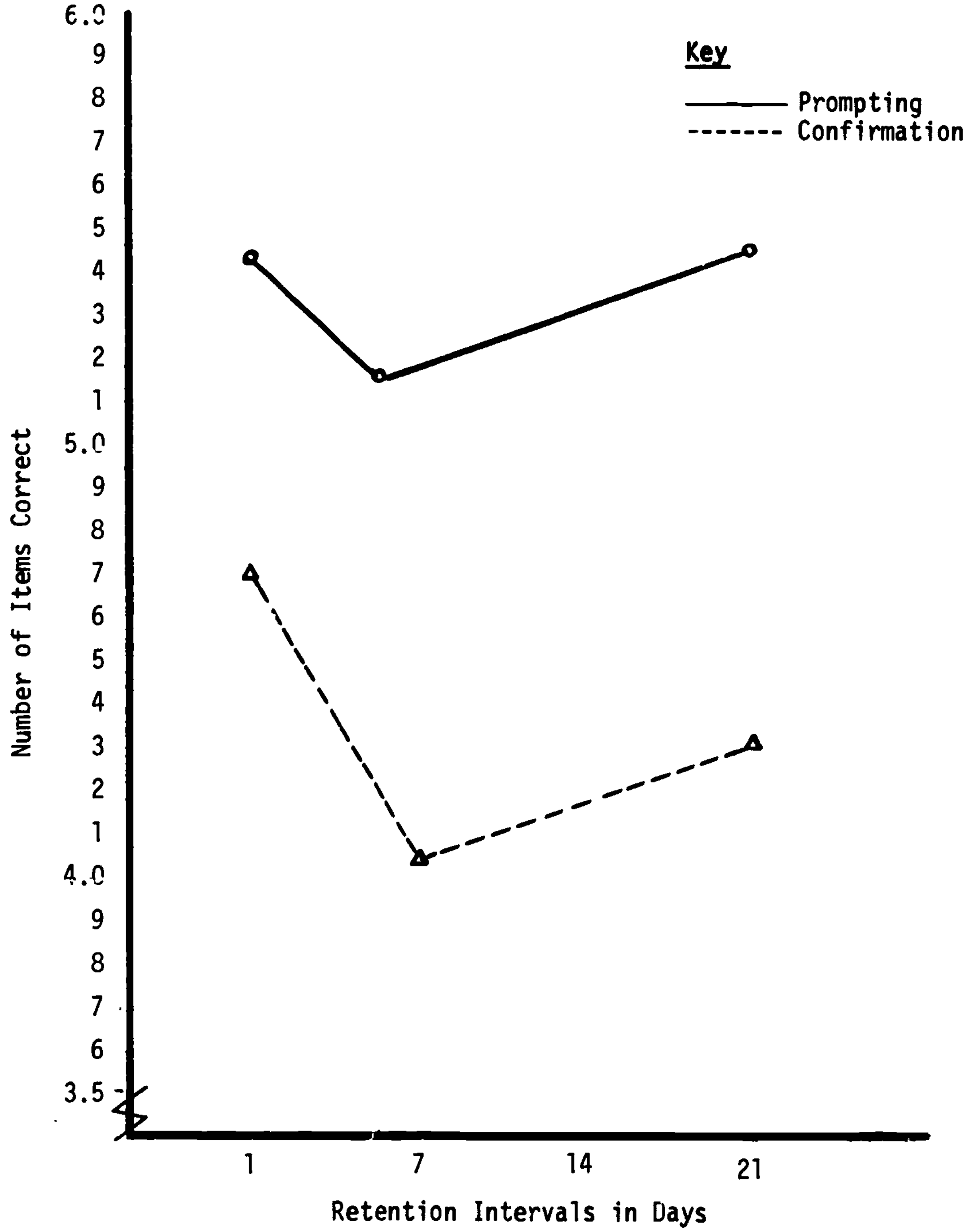

Fig. 5. Retention mean scores for items learned during the "first" treatment.

there is perhaps some contaimination in the data resulting from items which were not completely independent of each other making these data difficult to interpret. This conclusion is supported by both Figures 5 and 6 which indicate similar trends for the "first treatment" regardless of whether it was prompting or confirmation and similar trends for the "second treatment" regardless of whether it was prompting or confirmation.

Criterion level had the anticipated result of increasing acquisition time although again the data are not clear enough to interpret properly.

It seems highly desirable to further investigate the findings of Cook and Spitzer and Stolurow and Lippert in an attempt to apply them to computer-assisted instruction. A further refinement of the experimental materials is necessary along with improvements in the experimental design to provide the necessary control in the environment. Computer-assisted instruction offers the opportunity to manipulate variables of the kind investigated here which should lead to the preparation of improved instructional sequences.

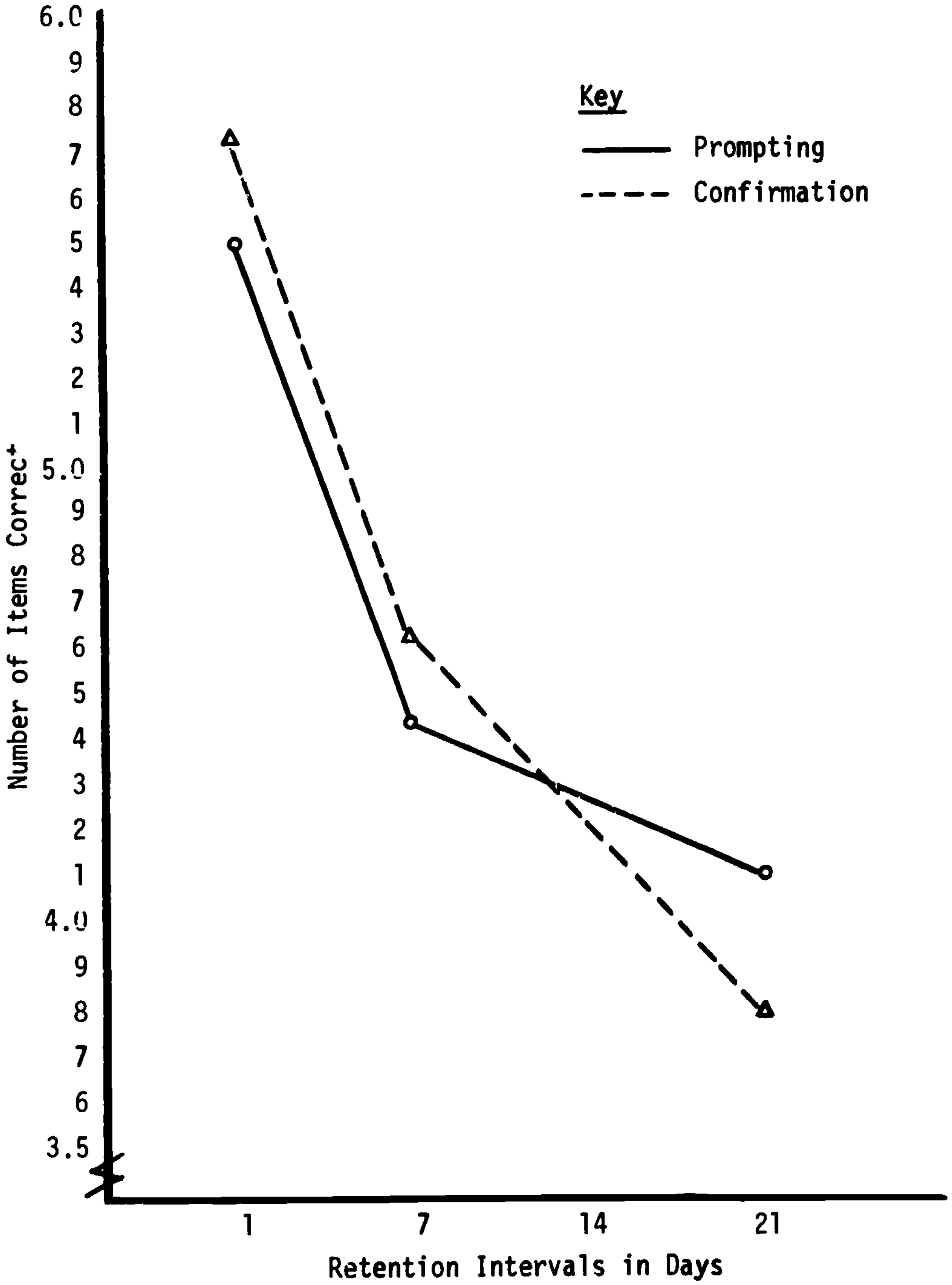

Fig. 6. Retention mean scores for items learned during the "second" treatment.

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Stolurow, L. M. and Lippert, J. Prompting, confirmation, and overlearning in the automated teaching of a sight vocabulary. Department of Health, Education, and Welfare, Cooperative Research Project, Contract SAE 8370. University of Illinois: Institute for Research of Exceptional Children, April, 1962.

ANALYSIS OF STUDENT PERFORMANCE RECORDS

Frederick N. Chase and Terry A. Bahn

Although extensive information about a student's progress through a course can be recorded by the IBM 1500 instructional system, the need to select, organize, and analyze these data for researchers and curriculum development specialists has been a need not fully met by the standard 1500 system. The single capability provided as part of the 1500 system for the output of performance data is that of listing on paper a student's "performance records" in chronological order. (Appendix A). By this means all data about a given student can be retrieved, but in a format ill-suited for many types of subsequent analysis. In particular, if one wishes to analyze several students' responses to a given question, one must shuffle through each student's listing. If one wishes to do further machine processing of the performance data, the relevant information must again be made machine-readable (e.g., key punched) by humans, with ensuing loss of time and accuracy.

Recognizing this inadequacy, many users of 1500 systems have developed their own methods of selecting, organizing, and analyzing student performance data. All such methods of "data management" known to us as of fall 1968[1] were investigated and rejected for one or more of the following reasons: 1) did not meet our objectives; 2) was not compatible with our 1130 based system; 3) 1132 printer which was used is too slow to provide acceptable turn-around time; 4) available documentation was inadequate; or 5) date of completion of data management package was uncertain.

In view of these problems, the staff at Penn State decided to write the performance record analysis programs described in this paper. We have capitalized on our past experience with data management programs (1) and on the availability of large computers on the University campus. Very briefly, the programs allow one to select, sort, and print data from raw tape performance files. An optional statistical analysis is possible after sorting and before printing.

[1]These were Florida State University (2); State University of New York at Stony Brook (5); and Stanford University.

The following sections describe the raw data which may be collected by the 1500 system for input to the analysis programs, the types of output available from the programs, and finally the means by which the output is obtained.

Input to the Performance Record Analysis Programs

After a student has responded to an instructional question and the response has been accepted and analyzed by the 1500 system, a "performance record" may be written[2] on magnetic tape. Each performance record can contain the course name, student name, identifying name of the Coursewriter II ep instruction which accepted the response, student response, date, time, and other information (3). The performance record is a permanent report of the status of the student at the time of his response. Any user (student or author) for whom performance recording was specified will cause records to be written as the computer accepts and analyzes his responses. These performance records are written one after another, in strict chronological order, on the performance magnetic tape.

Output From the Performance Record Analysis Programs

The Performance Record Analysis Programs provide three categories of output data for further analysis of the performance records logged during an instructional session. The remainder of this section describes these three categories at a medium level of detail.

Category R - Research. In preparation for meaningful output, records for one or more CAI sessions are combined. All records for given course segments and given dates are then selected from this agglomeration of records. The

---

[2] Whether a record is written depends on whether performance recording was requested at the time the student was registered and on the choice made by the course author to suppress or not suppress recording of a given response.
The input medium for the performance record analysis programs is tape, although the 1500 system is capable of writing the performance file on a disk.

tape resulting from this process can be given to a researcher for further, specialized analysis. Such a tape is one (currently the only) output option under Category R,(R is intended to suggest research).

This output could be used as input to certain library programs of other computers.

The second and third categories of output require a sort following the selection discussed above.

Category C - Course Development. In Category C,(C is intended to suggest course oriented analysis), a sort (by "ep identifier") collects performance records for a given part of the course (specifically, for a given answer request, i.e., a given ep Coursewriter instruction)[3]. Category C output is useful whenever one's perspective is course-oriented, i.e., whenever one wishes to focus on the status of all students as they passed a given point in the course.

Performance records used for Category C output are selected on the basis of a user-specified list of ep identifiers (all may be specified) and a user-specified list of student numbers (all may be specified here also).

After this selection has been completed, the desired records may be printed in full, or compressed into a condensed form of one printed line for each instructional question. (See Appendix A).

If the records are to be printed in full, the user may request that any combination of the following parts of the performance records be printed:

1. course name and segment number
2. student number
3. ep identifier (the author-specified name of the response request or ep instruction)
4. response latency (time for student to respond)
5. match identifier (the two character name of the instruction whose operand matched the students' response)
6. date of recording
7. time of recording

[3]Full specifications of the sort are first by segment of the course, then by ep identifier within segments, then by student number within ep's then by date, finally by time.

8. response length (number of characters)
9. number of times this student has previously responded to this ep.
10. switches
11. counters
12. student response

Category C output might be used to scan all student responses to questions in a course.

If the one-line summary is requested, each one-line summary contains the ep name, the number of students who responded to that ep, the total number of attempts on that question, the mean number of attempts (quotient of previous two numbers), the mean number of seconds in a response, and the fraction of all students responding more than twice to the ep. This output might be used to select for detailed inspection the questions for which the average student responds several times before he is allowed to proceed.

Category S - Student Trace. In Category S, (S is intended to suggest student-oriented analysis), a sort by student number[4] collects all responses for a given student (Appendix A). Within a given student's responses, entries are still ordered chronologically. Category S output is useful whenever one's perspective is student-oriented, i.e., whenever one wishes to follow a student through the course without regard to other students who may also have taken the course.

Performance records in Category S are selected as in Category C, i.e., by ep identifier and student number. After this selection is completed, the desired records are printed in full with a choice as to parts of each record which will be printed identical to the choice available under the full print-out option in Category C.

Category S output could be used to debug a course.

[4]Full specifications of the sort are: first by segment of the course; then by student number within segments; then by date; finally by time.

Flow of Data During Analysis of Performance Records

At various stages in the process of obtaining student performance records, the data is manipulated by four programs. These programs will be described briefly in this section.

After performance records have been collected on a number of small tapes (approximately 600 feet), Program 1, an IBM 1130 Disk Monitor FORTRAN program, is used to stack these tapes onto a large tape (approximately 24000 feet). In addition, this program changes the variable length CORE IMAGE records into fixed-length (232 byte) records which are in a simple format used by later programs (Appendix B). This stacking is necessitated by the fact that 1500 tape performance files cannot be reopened for additional recording sessions subsequent to the first recording session.

When Program 1 is initiated, it checks the output tape to be certain that it has a valid IBM 360/OS label. It then checks the input tape for a valid IBM 1500 OS performance tape label. At the end of the input tape, the operator is given the option to mount another input tape or to terminate the job. If a new tape is mounted, its label will be checked before stacking continues. The program includes a number of error recovery routines to handle label, record and tape errors.

Program 1 has 3 major subroutines: MAGTP is a modified version of MAGTA, an IBM Type III FORTRAN subroutine for reading magnetic tape (4). MAGTP differs from MAGTA as follows: a) EOF and tape errors are indicated in an additional argument so that they may be handled by the main program rather than by the routine itself; b) one rather than two word integers are used; and c) back-spacing after an unrecoverable read/write error is not automatic so that damaged records may be skipped. EXPAN is a FORTRAN callable subroutine written in IBM 1130 Disk Monitor Assembly Language. It is this routine which converts the raw input records into formatted, fixed-length output records. KLOZE is a FORTRAN subroutine which writes IBM 360/OS Trailer labels on the output tape when stacking is terminated.

Program 2 is FORTRAN IV main program run under IBM OS/360. Its purpose is to select records on the basis of course name, segment number(s), beginning and ending date, from the master tapes created by Program 1. These records are

written on a tape which will be used as input to Program 3. If the segment number, beginning date or ending date parameters are omitted, they will be ignored as a basis of selection, i.e. all segments, all dates, or all dates before or after a single specified date will be selected.

Program 3 is the IBM OS/360 Sorting/Merging Program. It can sort the records selected by Program 2 in any order on any data field(s). However, two major sorts have been used to date: 1) time of recording within date within student number within <u>ep</u> identifier within course segment--this sort is used for Category C output and 2) time of recording within date within student number within course segment--used for Category S output.

Program 4 is a FORTRAN IV main program. It povides a full listing and/or statistical summary of the sorted performance records which may be further selected on the basis of student number(s) and/or <u>ep</u> identifier(s). As in previous selections, if either parameter is omitted, all student numbers and/ or <u>ep</u> identifiers available for the course are included.

Future Developments

The latter three of the programs described above are currently operating under OS/360 on an IBM 360/67 computer. The source language is Fortran IV. The program package should thus be adaptable to any larger computer with a Fortran compiler and a library sort program. A possible problem in using a computer other than an IBM 360 is the need for Fortran character comparing subroutines.

Plans for future extension and improvement of the programs include provision of an option in Category R for output which is suitable for direct input to library statistical analysis programs.

Appendix A

This appendix contains a sample section of Coursewriter II code and the various types of output which can be generated for students who encountered that code while on-line. The interrelations of the various types of output are illustrated.

Fig. 1.

The course listing (Fig. 1.) shows part of a sample frame from a course segment called stat-5. The frame begins with pr op code. Then the computer is instructed to enter and process the student's response (ep op code). The author has specified an ep identifier of 0520000000. Following the ep op code are the response analysis instructions. Various possible answers are tested for. If one of these is found, appropriate action is taken. If the student types 74.3, he is given the message at 167-17 and branched to label 180.

Statement 3 of this program (dt 0,0Ø2 ...) causes the numeral 20 to appear on the cathode ray tube. This refers the student to the following problem in his handbook:

> Problem 20: Given a normal distribution with n = 302, how many cases will have z scores which deviate from the mean z of zero by an absolute value of 1.16 or more?

The student has been asked to solve the problem prior to his session at the terminal and should be ready to input his response.

```
166*e
  1  pr   *e
  2  de   0Ø32*e
  3  dt   0,0Ø2,0Ø40,0Ø20.  *e
  4  ep   0,0Ø2,0Ø40,0Ø9999Ø99Ø0520000000*e
  5  dt   30,0Ø2,30Ø0,0Ø05-20-01*e
  6  dti  8,39Ø2,8Ø1,39Ø *e
  7  fn   edØØØ*r*rØ*i*iØ*c*c*e
  8  um   .Øsw*e
  9  aa   skipØaa*e
 10  br   184*e
 11  aa   *r*rgo to endØaa*e
 12  br   end*e
167*e
  1  aa   *Øaa*e
  2  ld   b0Øb2
  3  fn   edØØØ0
  4  fn   edØØØ1
  5  fn   edØØØ74.3Ø74.292Ø74.29Ø74.2*e
  6  fn   edØØØ228Ø227.708Ø227.71Ø227.7*e
  7  fn   edØØØ37Ø37.146Ø37.14Ø37.15Ø37.1Ø37.2*e
  8  fn   edØØØ114Ø113.854Ø113.85Ø113.8Ø113.9*e
  9  fn   mvØ*b*Øb0,0Ø1b*e
 10  fn   mvØ*b*Øb0Øa*e
 11  fn   edØØ,,bØbØb0Ø0bØ.bØ bØb *e
 12  fn   edØØØØb*e
 13  aa   74Øaa*e
 14  dt   ,0Ø2,Ø40,0Ø  o.k.Ø*e
 15  br   180*e
 16  aa   74.3Øaa*e
 17  dt   ,0Ø4,Ø40,0Ø  o.k. To the nearest whole number*c*i*his would be 74 case
s.Ø*e
 18  br   180*e
 19  aa   *Øaa*e
 20  fn   ltØb2ØØ73Ø75Øa*e
 21  dt   ,0ØC,Ø40,0Øo.k.  The proportion greater than 1.16*c*iis .123. The answ
er is given by the*c*inearest whole number, 74.*e
 22  br   180*e
 type control word
```

Fig. 1. Listing

Fig. 2.

A student, whose number is u9, encountered the course frame on January 15, 1969. The IBM-supplied perfor program produced the output shown in Fig. 2.

```
RESTART POINT PASSED =NO   RESTART PERFORMED =NO   PROCTOR WITH STUDENT = NO   STUDENT ANSWER =  5 CHARACTERS
91*76
C01      1  C02      1  C03      2  C04      0  C05      0  C06      3  C07      2  C08      0  C09      4  C10      0
C11      2  C12      0  C13      0  C14      0  C15      0  C16      0  C17      0  C18      0  C19      0  C20      0
C21      0  C22   5783  C23   4000  C24      0  C25      1  C26 -    1  C27 =16384  C28     12  C29      0  C30      0
S00 OFF S01 OFF S02 OFF S03 OFF S04 OFF S05 OFF S06 OFF S07 ON  S08 OFF S09 OFF
S10 ON  S11 OFF S12 OFF S13 ON  S14 OFF S15 OFF S16 OFF S17 OFF S18 OFF S19 OFF
S20 OFF S21 ON  S22 ON  S23 OFF S24 OFF S25 OFF S26 OFF S27 OFF S28 OFF S29 OFF S30 OFF S31 OFF

RECORD NUMBER       123  COURSE NAME STAT =   5  STUDENT NUMBER  U9   TIME OF RECORDING 05*42*4716  PM  DATE  01-15-69
RESPONSE IDENTIFIER 0519000000  MATCH IDENTIFIER  CC  LATENCY TIME  CO  0023*2  SECONDS
RESTART POINT PASSED =YES  RESTART PERFORMED =NO   PROCTOR WITH STUDENT = NO   STUDENT ANSWER = 14 CHARACTERS
68*24 91*76
C01      1  C02      1  C03      2  C04      0  C05      0  C06      3  C07      2  C08      0  C09      4  C10      0
C11      2  C12      0  C13      0  C14      0  C15      0  C16      0  C17      0  C18      0  C19      0  C20      0
C21      0  C22   5783  C23   4000  C24      0  C25      1  C26 -    1  C27 = 8192  C28     12  C29      0  C30      0
S00 OFF S01 OFF S02 OFF S03 OFF S04 OFF S05 OFF S06 OFF S07 ON  S08 OFF S09 OFF
S10 OFF S11 OFF S12 OFF S13 OFF S14 OFF S15 OFF S16 OFF S17 OFF S18 OFF S19 OFF
S20 OFF S21 ON  S22 ON  S23 OFF S24 OFF S25 OFF S26 OFF S27 OFF S28 OFF S29 OFF S30 OFF S31 OFF

RECORD NUMBER       124  COURSE NAME STAT =   5  STUDENT NUMBER  U9   TIME OF RECORDING 05*45*3333  PM  DATE  01-15-69
RESPONSE IDENTIFIER 0520000000  MATCH IDENTIFIER  AA  LATENCY TIME  CO  0169*4  SECONDS
RESTART POINT PASSED =YES  RESTART PERFORMED =NO   PROCTOR WITH STUDENT = NO   STUDENT ANSWER =  8 CHARACTERS
74*3
C01      1  C02      1  C03      2  C04      0  C05      0  C06      3  C07      2  C08      0  C09      4  C10      0
C11      2  C12      0  C13      0  C14      0  C15      0  C16      0  C17      0  C18      0  C19      0  C20      0
C21      0  C22   5783  C23   4000  C24      0  C25      1  C26 -    1  C27 = 4096  C28     12  C29      0  C30      0
S00 OFF S01 OFF S02 OFF S03 OFF S04 OFF S05 OFF S06 OFF S07 ON  S08 OFF S09 OFF
S10 OFF S11 OFF S12 OFF S13 OFF S14 OFF S15 OFF S16 OFF S17 OFF S18 OFF S19 OFF
S20 OFF S21 ON  S22 ON  S23 OFF S24 OFF S25 OFF S26 OFF S27 OFF S28 OFF S29 OFF S30 OFF S31 OFF

RECORD NUMBER     - 125  COURSE NAME STAT =   5  STUDENT NUMBER  U9   TIME OF RECORDING 05*45*6265  PM  DATE  01-15-69
RESPONSE IDENTIFIER 0392000000  MATCH IDENTIFIER  UU  LATENCY TIME  CO  0013*0  SECONDS
RESTART POINT PASSED =NO   RESTART PERFORMED =NO   PROCTOR WITH STUDENT = NO   STUDENT ANSWER =  4 CHARACTERS
GO
C01      1  C02      1  C03      2  C04      0  C05      0  C06      3  C07      2  C08      0  C09      4  C10      0
C11      2  C12      0  C13      0  C14      0  C15      0  C16      0  C17      0  C18      0  C19      0  C20      0
C21      0  C22   5783  C23   4000  C24      0  C25      1  C26 -    1  C27 = 4096  C28     12  C29      0  C30      0
S00 OFF S01 OFF S02 OFF S03 OFF S04 OFF S05 OFF S06 OFF S07 ON  S08 OFF S09 OFF
S10 OFF S11 OFF S12 OFF S13 OFF S14 OFF S15 OFF S16 OFF S17 OFF S18 OFF S19 OFF
S20 OFF S21 ON  S22 ON  S23 OFF S24 OFF S25 OFF S26 OFF S27 OFF S28 OFF S29 OFF S30 OFF S31 OFF

RECORD NUMBER       126  COURSE NAME STAT = 100  STUDENT NUMBER  U9   TIME OF RECORDING 05*47*9366  PM  DATE  01-15-69
RESPONSE IDENTIFIER 0392000000  MATCH IDENTIFIER  AA  LATENCY TIME  CO  0128*7  SECONDS
RESTART POINT PASSED =YES  RESTART PERFORMED =YES  PROCTOR WITH STUDENT = NO   STUDENT ANSWER =  4 CHARACTERS
0
C01      1  C02      1  C03      2  C04      0  C05      0  C06      3  C07     32  C08      0  C09      2  C10      7
C11      2  C12      0  C13      0  C14      0  C15      0  C16      0  C17      0  C18      0  C19      0  C20      0
C21      0  C22   5783  C23   4000  C24      0  C25      2  C26      0  C27      0  C28     12  C29     14  C30      0
S00 OFF S01 OFF S02 OFF S03 OFF S04 OFF S05 OFF S06 OFF S07 ON  S08 OFF S09 OFF
S10 OFF S11 OFF S12 OFF S13 OFF S14 OFF S15 OFF S16 OFF S17 OFF S18 OFF S19 OFF
S20 OFF S21 ON  S22 ON  S23 OFF S24 OFF S25 OFF S26 OFF S27 OFF S28 OFF S29 OFF S30 OFF S31 OFF
**END
```

Fig. 2. Performance Output

Fig. 3.

In Fig. 3, is a page from our Category S output. The listings in Fig. 2 and Fig. 3 are seen to have the same structure and information content, the primary differences being in format and in the means by which the listings were produced. We feel that the format of our Category S output is considerably more legible, due primarily to the columnar arrangement of data and the suppression of unneeded labeling. The perfor output was done on the 1500 printer, while the Category S output was produced on a high-speed printer at Penn State's Computation Center.

```
COURSE SEG   S    ER IDENT.   LATENCY  MATCH    DATE     TIME     RL ATMPTS SWITCHES              COUNTERS

STAT    5   U9    0519033800     6.1     CC     1/16/69  17:39.97   5   3   000000 ( 1- 5)    1      1      2      0     0
                                                                            00100  ( 6-10)    3      2      0      2     0
                                                                            10010  (11-15)    2      0      0      0     0
                                                                            00000  (16-20)    0      0      0      0     0
                                                                            01100  (21-25)    0   5783   4000      0     1
                                                                            000000 (26-30)   -1 -16384     12      0     0
        RESPONSE - -1.96

STAT    5   U9    0519040100   116.3     AA     1/15/69  17:42. 4   5   1   000000 ( 1- 5)    1      1      2      0     0
                                                                            00100  ( 6-10)    3      2      0      2     0
                                                                            10010  (11-15)    2      0      0      0     0
                                                                            00000  (16-20)    0      0      0      0     0
                                                                            01100  (21-25)    0   5783   4000      0     1
                                                                            000000 (26-30)   -1 -16384     12      0     0
        RESPONSE - 91.76

STAT    5   U9    0519000000    23.1     CC     1/15/69  17:42.47  12   1   000000 ( 1- 5)    1      1      2      0     0
                                                                            00100  ( 6-10)    3      2      0      2     0
         RESTART POINT PASSED                                               00000  (11-15)    2      0      0      0     0
                                                                            00000  (16-20)    0      0      0      0     0
                                                                            01100  (21-25)    0   5783   4000      0     1
        RESPONSE - 68.24 91.76                                              000000 (26-30)   -1  -8192     12      0     0

STAT    5   U9    0520000000   169.3     AA     1/15/69  17:45.33   6   1   000000 ( 1- 5)    1      1      2      0     0
                                                                            00100  ( 6-10)    3      2      0      2     0
         RESTART POINT PASSED                                               00000  (11-15)    2      0      0      0     0
                                                                            00000  (16-20)    0      0      0      0     0
                                                                            01100  (21-25)    0   5783   4000      0     1
        RESPONSE - 74.3                                                     000000 (26-30)   -1  -4096     12      0     0

STAT    5   U9    0352000000    13.0     UU     1/15/69  17:45.62   2   1   000000 ( 1- 5)    1      1      2      0     0
                                                                            00100  ( 6-10)    3      2      0      2     0
                                                                            00000  (11-15)    2      0      0      0     0
                                                                            00000  (16-20)    0      0      0      0     0
                                                                            01100  (21-25)    0   5783   4000      0     1
        RESPONSE - GO                                                       000000 (26-30)   -1  -4096     12      0     0
```

Fig. [illegible] ato ory S ou put

Fig. 4 and Fig. 5

The Category C (course-oriented) output in Fig. 4 shows Student u9's one performance record and also at the same place in the listing all other performance records for ep number 0520000000. The one-line summary (Fig. 5) gives for ep 0520000000 a condensation of the data displayed in Fig. 4. Reading from the left, we note that for this ep, six students collectively gave eleven responses. About sixteen per cent (1 out of 6) of the students tried more than twice. On the average, a student tried 1.8 times on this frame. A typical student spent about 50 seconds responding.

```
COURSE SEQ   S   SP IDENT.    LATENCY  MATCH    DATE      TIME     NL ATMPTS SWITCHES                COUNTERS

STAT   5  U10  052CCCCCCC   18.5    AA    1/15/69  17:41.77   2    1   0CC000 ( 1- 5)    0     C     3    1   C
                                                                     00100  ( 6-10)    1     1     0    1   0
                                                                     10000  (11-15)    C     C     C    0   0
                                                                     00000  (16-20)    0     C     0    0   0
                                                                     01100  (21-25)    C   5783  4C0C   0   1
                                                                     CC0000 (26-30)   -1  -8192    12   C   0
       RESPONSE - 38

STAT   5  U10  052CCCCCCC   56.5    AA    1/15/69  17:44.67   2    2   0CC00C ( 1- 5)    C     C     3    1   C
                                                                     C0100  ( 6-10)    1     1     C    1   0
                                                                     1C000  (11-15)    0     0     0    C   0
                                                                     CC0CC  (16-20)    C     C     C    C   0
                                                                     C1100  (21-25)    0   5783  400C   0   1
                                                                     CC0000 (26-30)   -1  -4096    12   C   C
        RESTART POINT PASSED
       RESPONSE - 74

STAT   5  U4   052CCCCCCC   16.1    AA    1/15/69  18: 2. 1   4    1   080000 ( 1- 5)    2     C     3    0   C
                                                                     CC100  ( 6-10)    0     2     C    1   0
                                                                     CC000  (11-15)    0     0     0    0   0
                                                                     CC0CC  (16-20)    C     C     C    0   0
                                                                     C1100  (21-25)    0   5783  4C00   0   1
                                                                     C00000 (26-30)   -1  -4096    12   C   0
        RESTART POINT PASSED
       RESPONSE - 74.3

STAT   5  U5   052CCCCCCC   16.8    WW    1/15/69  17:28.7C   4    1   60C001 ( 1- 5)    C     C     2    0   1
                                                                     1C100  ( 6-10)    0     1     0    0   0
                                                                     CC010  (11-15)    0     C     C    0   0
                                                                     CC00C  (16-20)    C     C     C    0   0
                                                                     C1100  (21-25)    C   5733  400C   0   1
                                                                     C00000 (26-30)   -1  -8192   140   0   C
       RESPONSE - 228

STAT   5  U5   C52CCCCCCC   20.2    WW    1/15/69  17:31.47   4    2   0C0001 ( 1- 5)    C     C     2    0   1
                                                                     1C100  ( 6-10)    C     1     C    0   0
                                                                     CC010  (11-15)    C     0     0    0   0
                                                                     CG00C  (16-20)    C     C     C    C   0
                                                                     C1100  (21-25)    0   5783  4000   0   1
                                                                     CCC000 (26-30)   -1  -8192   14C   0   C
       RESPONSE - .246

STAT   5  U5   052CCCCCCC    5.8    AA    1/15/69  17:32.56   4    3   0CC001 ( 1- 5)    C     C     2    0   1
                                                                     10100  ( 6-1C)    0     1     C    0   0
                                                                     CC010  (11-15)    0     0     0    0   0
                                                                     C000C  (16-2C)    C     C     C    0   0
                                                                     C1100  (21-25)    0   5783  4000   0   1
                                                                     C00000 (26-3C)   -1  -4096   14C   0   C
        RESTART POINT PASSEC
       RESPONSE - 74.3
```

Fig. 4. Category C Output - Continued on following page.

```
COURSE SEC   S    EP IDENT.   LATENCY  MATCH    DATE     TIME     RL ATMPTS SWITCHES            COUNTERS

STAT    5   U6   052CCCOCCC    56.6    AA     1/15/69  17:33.26   4    1   OCC000 ( 1- 5)   C    C    3    C   1
                                                                            00100 ( 6-1C)   1    2    C    C   0
                                                                            10000 (11-15)   1    C    C    C   0
                                                                            0C000 (16-2C)   0    0    C    0   0
                                                                            C1100 (21-25)   0  5783 4000   C   1
                                                                           C00000 (26-3C)  -1 -8192   12   C   0

        RESPONSE - 37.7

STAT    5   U6   052CCC0CCC    56.7    AA     1/15/69  17:37.30   6    2   OCC000 ( 1- 5)   0    0    3    0   1
                                                                            0C10C ( 6-1C)   1    2    C    C   0
                                                                            10000 (11-15)   1    1    0    C   0
          RESTART POINT PASSEC                                              CC00C (16-2C)   C    C    C    C   C
                                                                            01100 (21-25)   0  5783 4000   C   1
                                                                           CC0000 (26-3C)  -1 -4096   12   C   0
        RESPONSE - 0

STAT    5   U8   052COCCCCC   106.5    WW     1/15/69  17:11.75   3    1   CCC000 ( 1- 5)   C    C    2    C   C
                                                                            C010C ( 6-1C)   C    1    0    C   1
                                                                            CC01C (11-15)   C    C    C    C   0
                                                                            CC00C (16-2C)   C    0    0    0   0
                                                                            C1100 (21-25)   C  5783 4000   0   1
                                                                           CC0000 (26-3C)  -1 -8192   12   0   0

        RESPONSE - 228

STAT    5   U8   052CCCGCCC    15.3    AA     1/15/69  17:12.18   2    2   CC0000 ( 1- 5)   0    C    2    0   C
                                                                            CC100 ( 6-1C)   0    1    C    0   1
                                                                            0C010 (11-15)   C    0    0    0   0
          RESTART POINT PASSEC                                              00000 (16-20)   C    C    0    C   0
                                                                            01100 (21-25)   0  5783 4000   0   1
                                                                           C00000 (26-30)  -1 -4096   12   0   C
        RESPONSE - 74

STAT    5   U9   052CCCCCOC   169.3    AA     1/15/69  17:45.33   6    1   CC0000 ( 1- 5)   1    1    2    C   C
                                                                            CC100 ( 6-1C)   3    2    C    2   C
                                                                            00000 (11-15)   2    0    C    0   C
          RESTART POINT PASSEC                                              0C00C (16-2C)   0    C    0    0   C
                                                                            01100 (21-25)   0  5783 4000   C   1
                                                                           0C0000 (26-3C)  -1 -4096   12   C   0
        RESPONSE - 74.3

STAT    5   U10  052C010CCC    26.6    CC     1/15/69  17:42.24   4    1   OCC000 ( 1- 5)   C    0    3    1   C
                                                                            CC100 ( 6-1C)   1    1    C    1   0
                                                                            10000 (11-15)   0    0    0    0   C
                                                                            C0000 (16-2C)   C    0    C    0   0
                                                                            01100 (21-25)   C  5783 4000   0   1
                                                                           CC0000 (26-3C)  -I -8192   12   C   0

        RESPONSE - .377
```

Fig. 4. Category C Output - Continued from preceeding page.

EP IDENTIFIER	STUDENTS	ATTEMPTS	% ATTEMPTS > 2	MEAN ATTEMPTS	MEAN LATENCY
0509C000CC	6	16	50	2.67	94.20
0509030100	4	4	0	1.00	26.95
0515C00000	6	17	33	2.83	47.24
0519C00000	6	11	0	1.83	44.09
0519C40100	4	7	25	1.75	50.69
0520C00000	6	11	16	1.83	49.56
C520C10000	2	2	0	1.00	46.55

STUDENT PERFORMANCE RECORDS FOR "STAT ," REQUESTED BY TERRY A. BAHN , COMPLETED.

Fig. 5. Summary

Appendix B

Penn State Fixed Length 1500 Performance Records Format

Bytes	Contents	Number of Bytes	Format
1-2	Number of 2-Byte Words in Student Response	2	Binary
3	Restart Point Passed "Switch"	1	EBCDIC
4	Restart Performed "Switch"	1	EBCDIC
5	Proctor With Student "Switch"	1	EBCDIC
6-9	Time of Recording	4	Binary
10-13	Student Number	4	EBCDIC
14-18	Course Name	5	EBCDIC
19-20	Segment Number	2	Binary
21-22	Month	2	Binary
23-24	Day	2	Binary
25-26	Year	2	Binary
27-36	EP Identifier	10	EBCDIC
37-38	Match Identifier	2	EBCDIC
39-138	Student Response	100	EBCDIC
139-200	Counters 0 Through 30	62	Binary
201-232	Switches 0 Through 31	32	EBCDIC

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SURVEY OF COMPUTER SCIENCE LITERATURE RELEVANT TO CAI

Paul Rowe

Introduction

The purpose of this paper is to review and discuss some computer science articles published in scientific journals over the past ten years. Many of the ideas and developments in these articles are quite new; several were published in 1967 and 1968. The goal in discussing these articles is an attempt to evaluate their potential usefulness to CAI. The word 'potential' is used because even the best idea is not useful unless it is implemented, and the question of adoption of the ideas in these articles will depend on decisions made by many different people.

The author of this paper does not claim a complete literature search in this area, although in an attempt to cover this area of computer science, a very extensive literature search was made that involved the Pattee Library, the Math Reading Room, the Engineering Library, the Physics-Cnemistry Library, all on the Penn State University campus. In an attempt to cover this area of computer science, some private correspondence with computer scientists at other universities was initiated; however, very little new material resulted from this source.

Computer Languages

There is an extensive amount of research and study currently being conducted on both natural and artificial languages. This work ranges from the mathematical study of context-free languages to empirical studies of natural languages. Since communication between man and computers utilizes artificial languages, no further mention of natural languages will made in this paper. The set of computer languages is a proper subset of artificial languages. The reason for this is that there are many artificial languages which have interesting and important theoretical properties but have very limited capabilities as man-computer communication languages.

Computer languages generally have been developed by one of two different, but not entirely unrelated, methods. The following disucssion will be an oversimplification of the two methods. The first method consists of specifying the source statements as to form and purpose. A processer is then written to

process the source statements into machine language statements that will accomplish the original purpose of the source statements. In the most elemental form of this method, no attempt is made to have the source statements contain any theoretical properties. The second method consists of specifying the theoretical properties of the source language as to form and purpose, but they must fit the theory. Finally, as in the first method, a processor is written to obtain machine language statements. It is obvious that one could develop a computer language by a combination of the two methods. For example, a subset of the source statements could be required to be context free, and the rest of the source statements specified without regard to any theory. ALGOL is an example of a computer language developed by the second method. There is merit to both methods. The first method is less restrictive on the specifications of source statements. Use of the second method gives greater assurance that the language developed will be unambiguous and have other properties that are considered desirable by the people developing the language.

There have been two languages developed specifically for CAI (Coursewriter I and Coursewriter II). Other computer manufacturers have developed their own CAI languages for their computers, but these will not be discussed in this paper. Typical of CAI languages developed thus far, each one has been developed for a particular computer. Since Coursewriter was developed with a specific computer in mind (presumably IBM 1800/1130) any change to a larger, more capable computer will probably necessitate at least a modification of the present software if not the adaption of a different language or the development of a new language. There is a need for using more capable and faster hardware to bring down the cost of CAI. Even with the present system (IBM 1500), there is need for modification of the present software to enhance the use of CAI. Therefore, there is a need to look at various existing languages which might be capable of adapting to CAI and also the possibility of developing a new language for CAI.

There are several existing languages which might be adapted to CAI. One that has already been used with IBM 360 systems is Iverson's 1962 APL. Text handling capabilities were added to APL. Several languages have been developed for human-computer communication in an interactive mode. These languages either do or could be modified to use the various CAI input-output devices. One of the most recent of these was developed by Kulsrud (1968). Actually

Kulsrud did more than develop a new language for graphic display and other input-output devices; he showed that such languages could be obtained by syntax specification and that these languages and their processers could be acquired relatively quickly. If the idea of a new CAI language is ever considered, it would be worthwhile to make a thorough study of this and similar languages. Other languages that one might consider are Dialog (Cameron, 1967) and Pose (Schlesinger, 1967). There will probably be more new interactive languages developed in the near future.

If a larger and more capable computer than the IBM 1500 (1130 base) is used for CAI, perhaps it would be best to develop an entirely new language. If the present research on the theory of computer languages continues, it should soon be possible to get desired properties of the language by specifying the theory that the language must satisfy. Several articles report progress that has been made in this direction. For example, the article on context-free languages by Parikh, 1966. Thus it is known that a context-free grammar does not always generate an unambiguous language. Ways of modifying the grammar are known so that an unambiguous language always results. However, this is sometimes too restrictive on the resulting language. Research in this area still appears to be active. Ginsburg, Greibach, and Harrison have done much work on the theory of languages (Ginsburg, 1967; Greibach, 1968; and Ginsburg, 1968). Other articles of interest include Aho (1968) and Knuth (1968). To implement a new language, it is necessary to obtain a processor. The ease with which this can be done is an important consideration. Some recent papers have an important bearing on this. The article "Stack Automata and Compiling," by Ginsburg, Greibach, and Harrison (1967), and the small book _A Syntax Oriented Translator_ by Ingerman (1966) are both relevant. There are many more articles that will not be listed in this paper. Perhaps the most important contribution to showing how processors could be obtained quickly was "A Formalism for Program Translation" by Sklansky, Finkelstein, and Russell (1968). They describe a formalism for representing sequences or networks of program translations and compiler translations. It should be easy to extend their formalism to other type processors. Their formalism permits very complicated translation sequences to be followed and extended easily.

Theory of Programing

Not as much work has been done on this subject as on languages; however, some papers have been published and interest seems to be increasing. Some of this may be more important to CAI than the theory of languages. Two rather general articles on the theory of computation were published by McCarthy (1962 and 1967). The article "Assigning Meanings to Programs" was published by Floyd (1967). Its purpose was to provide a basis for formal definitions of the meanings of programs, such that a rigorous standard is established for proofs of correctness, equivalence, and termination of computer programs. The results and methods of this article should be applicable to programs written in most computer languages including present and future CAI languages. A method for systematic error analysis of computer programs was developed by Miller (1963). The method uses concepts from graph theory and Boolean matrices. The method requires a flow chart of the program, which is a drawback for applications to CAI. This is true especially when on-line authoring is done. However, programs can be written that will analyze a program and produce the equivalent of a flow chart.

A paper by Karp (1960) discusses the application of graph theory to digital computer programing. He defines a graph-theoretic model for the description of flow charts and programs. He shows that the properties of directed graphs and of the associated connection matrices can be used to detect errors and eliminate redundancies in programs. He also shows that these properties can be used in the synthesis of composite programs. He then expands the graph-theoretic model to take into account frequencies of execution of portions of a program and solves a problem of optimum arrangement of a program in storage. This paper could be very important to CAI as the programs written in Coursewriter II or any other CAI language become more complex and sophisticated. However, it will take an effort to master the necessary techniques.

There are two more articles which are relevant to a discussion on the theory of programing. The first is a paper by Marimont (1960). This is a rather elementary paper on application of directed graphs and Boolean matrices to computer programing. This is probably a good starting place for a person who wants to learn the theory of programing. The second article was written by Martin and Estrin (1967). They discuss estimations of computing times for a program on a given processing system and the probabilities of reaching vertices in a graph model of computations.

Segmentation of Programs

It is difficult to say at this time whether the papers published on this subject will even be of practical importance to CAI. Programs written in Coursewriter II are read from disk into memory a segment at a time; therefore, segmentation of programs is used by CAI. However, one would have to try the ideas published on program segmentation to determine if any increase in efficiency were obtained. Schurmann (1964) wrote a paper on the use of graphs for the analysis of the distribution of loops in a program. Segmentation of a program is most efficient when the least number of loops are cut in the segmentation process. The problem of analyzing graphs by connectivity considerations is discussed in a paper by Ramanoorthy (1966). This is quite an advanced paper and requires a good mathematics background for complete understanding. An article by Marimont (1959) contains some ideas relevant to this topic. The problem she discussed concerns the checking of the consistency of precedence matrices. A short, but very good paper, on segmentation of programs was written by Berztiss (1968).

Parallel Computation and Parallel Computers

This is a controversial topic at the present time. The central idea is that modular or parallel computers could be built to share a large memory. A supervisory unit would assign tasks to the modular computers, but each computer would contain its own arithmetic and logical unit. This would be very good for CAI applications since several terminals could be serviced simultaneously. There are several articles on this subject and some are quite long. Much of the mathematical theory of parallel computation was developed by Dorn, Hsu, and Rivlin (1962). Their paper was intended mainly for numerical analysis, but the material on rearranging programs for efficient parallel computation is generally applicable to any computations that can be done simultaneously. A general mathematical model for modular computers is developed by Wagner (1964). His is a very long paper, and the only importance to CAI is to keep in mind that people are working on parallel computers and in the future such computers could be important in applications of computer science. Karp and Miller (1966) apply graph theory to the description and analysis of parallel computations. They obtain some very interesting results, both theoretical and practical. A

very good article by Schwartz (1963) gives a procedure for parallel sequencing with a choice of machines. In general this paper is easy to understand and has many good ideas.

One of the main problems in parallel programing is to determine all the computations and especially the least number of computations that must be performed before a given computation can be initiated. A paper by Hu (1968) discusses a decomposition algorithm for finding the shortest paths in a network. The author states that the algorithm can save on both amount of computation as well as storage requirements. An article by Schwartz (1961) describes an automatic assignment procedure for use for programing parallel computers. This paper is quite easy to read and should be a good starting place for one wanting to understand parallel programing and parallel computations.

Much too short a time was spent on each topic to be in any sense complete, and the many interconnections between the topics were barely considered. One topic was entirely omitted. Thus, none of the articles on man-machine interactions in a learning mode were included. There are articles due to come out soon on most of the subjects mentioned in this paper. Therefore, a revision of this paper should be made in the near future. This revision should discuss the published articles more thoroughly and include new papers on any topic relevant to CAI.

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PROGRAMED PATTERNS: A COMPUTER-ASSISTED APPROACH TO SPELLING

Helen L. K. Farr
James J. Kelly David D. Palmer

About the time that computer-assisted instruction (CAI) was first being developed, social and technological circumstances in the nation prompted Congress to increase federal appropriations for vocational and technical education. The almost simultaneous occurrence of these two events led to the development of the spelling course described here. One of the major problems vocational educators faced was that of interesting and motivating students who, in many cases, had experienced years of academic frustration and frequent failure. This problem was especially acute in the subject matter called "English" (or "language arts" or "communication skills"). Within English, both academic and vocational teachers reported a general deficiency in spelling skills among their post-high school students. So, because there was declared need for spelling instruction and because spelling is a comparatively easy portion of English to deal with in CAI, spelling was selected as appropriate subject matter for concentration.

An initial series of short courses (Hogan and Farr, 1966) had successfully demonstrated (Farr and Hogan, 1967) that CAI could be used to teach spelling to post-high school vocational-technical students. Those courses were presented on an IBM 1410 system, using typewriter terminals equipped with slide projectors and tape recorders. Therefore, when an IBM 1500 system using student stations equipped with cathode ray tubes (CRT) and image projectors replaced the 1410 typewriter terminals, the spelling course had to be translated for use on the new system. However, since the 1510 terminals presented much richer instructional opportunities, it was decided that the spelling course should be redesigned and restructured.

The primary purposes of this revision were to maximize the known capabilities and characteristics of CAI and to explore untried potentials of the 1510 terminals in teaching a thoroughly familiar--if unmastered--skill subject to young adults who had a history of failure or underachievement in that subject. For example, we considered the often criticized "impersonal" characteristics of the computer, and we decided that in teaching adults a subject

"they should have learned years ago," the absence of a human teacher-grader might be a distinct advantage. We also considered the computer's well-known capacities for presenting information according to a strategy, for accommodating student options, and for quickly analyzing and storing various amounts and kinds of data. These capacities could be extensively exploited in our spelling course when used in conjunction with teaching practices such as organization, discovery, prompting, and reinforcement. But most of all, we considered the distinctive visual capacities and characteristics of the CRT (essentially a television screen) for presenting a subject matter that most of our students could be expected, on the basis of past experience, to regard as stale, dull, and perhaps, as hopeless.

We recognized that negative student attitudes like these were fundamentally as challenging to course authors as the 1500 CAI system itself was. Therefore, a secondary purpose of our revision was to try to dispel the unfavorable attitudes associated with a spelling failures by making our presentation of the subject as different from past presentations as possible: technically, through CAI; and substantively, through restructuring the subject matter itself. To this end, we examined the content and structure of more than 20 spelling texts for elementary and secondary students. As a result of examining those textbooks, we decided to structure our revised course according to relevant linguistic principles, namely, componential analysis, pattern recognition, and rule formulation. These fundamental linguistic principles were not only appropriate to the five common spelling errors that we selected for instruction, but they also seemed particularly suitable for implementation on the 1510 terminals.

Concisely then, in our revised spelling course for post-high school students, we set out to innovate as much as was educationally and technically feasible in teaching an "old" subject to discouraged and/or bored young adults.

The revised program is nearly finished at this time. In the first half of 1969 it will be completed, thoroughly debugged, field tested, and tried out _in toto_. On the basis of preliminary student performances, some changes have been made, and others may be made after the field testing. The needed changes indicated and made so far, however, have been minor ones. Consequently, it is unlikely that the basic goals, rationales, strategies, structure, or presentation of the course will undergo extensive changes in the foreseeable future.

Aspects of a CAI Spelling Course

In planning and developing this course, we attempted to consider at all times the total learning situation and all of its aspects that might be relevant to our purposes. That is, before a decision was incorporated into any part of the course, we evaluated the usefulness and probable impact of the proposal from each of the following aspects: the station environment, the visual channel, the student-machine relationship, the educational objectives and rationale, and the CAI-CRT potential (i e., author objectives). Although these aspects are described and explained serially here, they were dealt with concurrently while we worked on the course

Environmental Aspects

In our CAI laboratory, the student does not usually see the IBM 1500 computer (where the spelling course is stored) unless he visits the machine room. Instead, he communicates with the computer by using student station equipment in a carrel-like arrangement. This location, called a "station," is roughly comparable to a student's desk or seat in a regular classroom, although the station also includes the physical tools of learning, which in a classroom might be things like paper, pen, chalkboard, etc. As he sits at his station, the student sees the following equipment.

1) Directly in front of him, on a desk-like surface is an electric typewriter keyboard which the student uses to type information to the computer.

2) Above the typewriter keyboard, a cathode ray tube (CRT) is mounted. The CRT looks like a television screen; but unlike an ordinary, home television screen, the tube permits two-way electronic communication between the student and the computer.

3) Attached to the side of the screen mounting is what appears to be a good-sized plastic pencil with an electrical cord attached to its eraser end. This object is a light pen and is used by the student to indicate his answers to the computer. When he touches the point of the light pen to designated areas of the screen, it is stimulated by light beams from that area of the screen and registers the impulse in the computer. In the 1500 system the light pen serves as a pointer rather than as a writing instrument.

4) Eventually, sound equipment will be installed to play audio tape recordings. Although it is not yet available, it is mentioned here because spelling courses often use aural presentations, especially in testing.

5) Students on this course are supplied a pencil and scratch paper to use if they choose, since many older people seem to partly judge correct spelling by a kind of "automatic writing," namely, by a kinetic process.

6) Although it may seem inappropriate to classify a human proctor as part of the environmental equipment at a CAI station, that is what she basically is for this course. Aside from checking the student in, assigning him a station, and showing him how to sign on initially, she has no special duties to perform for our adult spelling students.

Visual Channel Aspects

As the equipment listed indicates, this course uses the visual mode of communication almost exclusively (students type some responses). All of the material presented appears only on the CRT, because we decided to capitalize on the black-and-white television screen's capacity for movement rather than on the image projector's capacity for displaying colorful but static visuals. Color is often used in spelling textbooks and so might be fairly familiar to our older students. The occurrence of moving words and statements is much more rare, however, and so we chose to explore how movement within the textual material could be used in teaching spelling.

Because the visual channel of the 1510 station was being explored, the authors used the on-line input method almost exclusively, so they could immediately inspect what they had just put into the computer. That is, after planning and coding, on paper, a portion of material, the authors themselves used the typewriter to input the information to the computer. Then they had the computer display that portion of material on the screen; and, where it was necessary, they decided on changes, noted flaws or errors, and replanned the presentation. Macro programs (i.e., computer operations that recur frequently in a course) were, as they must be, put into the computer from punch-card decks.

If the visual motion dimension of CAI is under scrutiny, and if one is attempting to investigate the innovative use of that dimension, on-line input is, in the judgment of the authors of this course, the most effective means of input. Card input is certainly faster since it uses system time more efficiently, but for exploratory programing of the type accomplished in this course, it is a second-best method of input. Once the potentials of the computer-controled 1510 screen have been explored, and the desired effects achieved, it

is no longer so important for authors to do their own inputting on-line. Nevertheless, it seems to us that the on-line method of input may always have significance in imaginative, innovative CAI programing where the goal is not to transpose the text and format of a book on to a screen. Furthermore, once an author has taken the time necessary to investigate, develop, and implement a display technique or arrangement, it is a relatively simple and quick process for authors of other courses (often in different subject matters) to study, revise and adapt that technique for their own purposes. For, if what one author devises has application in other subject matter areas, it is obvious that a great deal of effort, system time, and money are saved by the users and modifiers of what the first author did. Therefore, the open and sustained exchange of ideas, experience, and criticisms among capable authors, programers, graphics personnel, and computer operators is as beneficial to the development of the technical aspects of CAI as are some changes in the technology itself--especially during early development.

If we had not recognized the challenges to our ingenuity and our effectiveness in trying to teach an "old" subject to "old" students, we might not have felt the necessity to explore the visual capacities of the 1510 terminal so thoroughly. Realizing the challenges, however, we were obliged to investigate and use techniques that might, according to some critics, seem to be sheer gimmickry. Unblushingly, we admit that some of our techniques may indeed border on gimmickry. But if these techniques help us capture the attention of jaded students so they learn what they have not learned from a variety of other teaching methods, then we must acknowledge that these are also pragmatic techniques. Behavioral objectives are important elements in CAI; for this course, our objectives included basic technical-visual explorations by the authors and improved spelling performances by the students.

Not all of the visual display techniques used in this course are unique to CAI; but most of them can be duplicated in teaching, only by using motion pictures, which, of course, have no provision for interacting with the student. The distinctive display techniques we incorporated to various degrees and for various purposes include the following: flashing letters and letter groups; moving letters and letter groups; horizontal, vertical, diagonal, and scattered letter and word arrangements; gradually appearing and disappearing text, a word or a line at a time; significant spacing and placing of text on the screen;

underlines, box frames, filled boxes, and other special visual cues; type in different sizes; special phonetic dictionary symbols; and pauses of varying lengths.

Concisely, in this course, the static page of a spelling text, that our students were accustomed to studying from, was replaced by a dynamic screen.

Student-Machine Aspects

The CAI system seemed to provide an unusually promising situation for teaching spelling to post-high school students for the following reasons:

1) For vocational and technical students, almost any activity involving a computer seems to have a fascination. For other older students the notion of being "taught by a computer" seems to produce curiosity and a somewhat awed amusement. In both student groups, therefore, the very concept of CAI provides a set for experiencing something new, unexpected, and unpredictable. The advantage of inducing such attitudinal sets in adult students who are about to once again encounter an "old" subject should not be underestimated. Further, this advantage should not be devalued as a one-time, novelty effect. Quite the contrary, if students experience--perhaps for the first time--success on this course, we can presume that they would have a favorable attitude toward it, and therefore, perhaps toward other CAI courses.

2) Everything that links the student with the computer is called the "interface"; (i.e., his terminal or station with its equipment, and the course he takes). In most cases, the interface is quite unlike the equipment and materials that older students are used to in studying spelling. So as the student approaches it initially, the interface does not evoke memories of past failures. If he is at all able to conceive of a fresh start on his spelling problems, the 1500 student station and its use in this course hold promise for that fresh start.

3) The on-line experience of CAI provides a particularly beneficial experience for older students who are used to "making mistakes." The apparent absence of personal, human criticism sharply reduces the likelihood of embarrassment and shame that these students have usually come to expect in classrooms. The absence of these presumably destructive reactions should promote learning--especially when the subject matter is admittedly elementary for adults.

4) The individualized nature of the CAI program and equipment encourages a student to stick with a problem or an instructional segment until he has mastered it. The shame, felt in a classroom, when a student does not know an answer is minimized in CAI, because his classmates do not know about his ignorance or mistakes. The embarrassment he may have felt when he "held up the whole class" with his errors or ignorance simply does not occur in the individualized setting of the CAI terminal

5) The mechanical character of CAI provides a very satisfactory scapegoat for an adult student, frustrated by repeated efforts to learn a given unit of relatively low-level information Without generating any guilt feelings, he can freely criticize the "dumb machine," argue with it, disapprove of its teaching, or the phrasing of its questions, and if he is really wrought up, he can walk off in a huff. All these things he can do without censure or retribution in CAI--but not in the regular classroom.

6) The tendency of students to anthropomorphize the computer probably results from the two-way communication that can take place in CAI. Thus, even if an unusually irritated student were to storm away from his terminal it is far more likely that he would return to try again than it would be if he had been using a conventional textbook or workbook based upon discrete, one-way communication. In other words, the pertinent CAI feedback tends to produce a sense of closure or a desire for closure, depending on its content. Except for a few programed ones, no spelling text ever told him his answer was right or wrong. And with programed texts, he was still left to check his own answers by using his admittedly shaky powers of spelling discrimination. The intrinsic interaction between this CAI program and the student compels him to be more deeply involved than he probably would be with a spelling text. Besides, who is going to admit that he was bested by a machine? For no matter how man-like CAI may sometimes seem to be, the student knows that it is still a machine. In short, the ambivalence that a CAI experience can generate may be advantageous.

7) Some of us have wondered how remedial students might react to being assigned CAI after they had failed to master material in class. We wondered whether they might feel that the teacher had given up on them and abandoned them to a machine--one that successful students might soon label "the dummy machine." But so far, we have no indications that our post-high school students (who must be classified as remedial students in spelling) have had these negative feelings about being "turned over to CAI." This fact may be due to some of the psychological factors mentioned above (e.g., not having to struggle unsuccessfully in front of other people) and/or to the student's realizing (as

he walks in and out) that whereas he may be taking a remedial course, students at other stations in our laboratory are not. Hence, he has no grounds for assuming that the machine stigmatizes him. We want to stress that while we are concerned with the advantages of using CAI to teach what may be considered remedial material to older students, it should be clearly understood that remediation is by no means the only (or the chief) domain of CAI. Our course was designed to help solve special learning problems for a particular student group. There are many other CAI uses and advantages that could be cited, but they are not relevant to the discussion of this course.

In summary, for our students and our course material, CAI seems to offer numerous advantages over other teaching methods. Because some of the student-machine aspects are intangible or largely unmeasured does not decrease their possible bearing on learning. Aside from a limited sampling of self-reported student attitudes, there is little empirical evidence about the student-machine dimension of the CAI situation. Nevertheless, that little evidence, combined with observations and logical deductions, indicates that (contrary to the fears of some) CAI is not dehumanizing; and it need not be cold, impersonal, or insufferably rigid. Realistically, for those who are in a plight similar to that of our spelling students (i.e., not being taught a required skill in class because it is regarded as too elementary for that level)--for students in a plight like this, an effective CAI course may provide a very gratifying and satisfying experience. In such circumstances, machines may be more humane than some humans.

Educational Aspects

Traditional Approaches. Spelling has usually been classified as a skill subject to be acquired in the elementary school. Generally, it has been taught in three ways (or in combinations of these): from teacher-assigned lists of words, from rules assumed to cover major spelling problems and/or their exceptions, and from student-compiled word lists based on listening, reading and marked errors on written work. Progress has usually been measured according to a test-teach-retest pattern. Test items are presented in either visual or aural form, rarely in both forms together. Students are required to write given words correctly, and/or to select correctly or incorrectly spelled words from a given group. Prerequisite skills for spelling (with varying criterion

levels depending on the grade level) have usually been considered to be the ability to read, write, memorize, and discriminate visually, aurally, and/or kinesthetically.

Usually, when students had spelling difficulties they were advised to memorize rules and/or lists of words dealing with their difficulties. Frequently such advice ended with the admonition that since there were so many exceptions to the rules, the students would just have to memorize the spelling of as many words as possible. Teachers said they were sorry, but that was how English spelling was: irregular, erratic, senseless. Consequently, poor spelling students tended to view the task of improving their spelling skills as an intrinsically hopeless one. For, if they memorized 50 words containing _ie_ or _ei_ combinations but were tested with words which weren't on their 50-word list or happened to be exceptions to the "_i_ before _e_" rule, they were as likely to fail the test as to pass it.

On written assignments, English teachers commonly marked spelling errors and often tallied them, deducting credit for the number and/or kinds of errors. Thus, on a 250 word composition, if a student in the upper school grades misspelled eight words, the composition might be given a failing grade, regardless of its content or style. Or, if two grades were given (one for content, one for skills) teachers often weighted the grades equally. In almost no case did anyone take note that on a 250 word composition a student making eight spelling errors had spelled 242 words correctly. In other words, correct spellings were, ordinarily, neither noticed nor rewarded with bonus points.

Spelling errors nearly always seemed to produce negative teacher criticism and subsequently negative student affect toward spelling. Apparently, at every level of schooling beyond the primary years, correct spelling has been, in fact, implicitly regarded as part of each student's entering skill behaviors, regardless of the explicitly listed objectives and criterion levels for different grades. Furthermore, in general conversation, when a speaker wants to indicate that someone epitomizes ignorance or stupidity, he is quite likely to say, "She's so dumb, she can't spell 'cat'." Thus, outside the classroom the lack of spelling skill has traditionally been associated with general inadequacy and failure. One misspelling in a letter from a stranger may influence the reader of the letter more than anything else on the page.

These, then, are the kinds of educational experiences (both intramural and extramural) that we could reasonably assume our post-high school students had had with spelling before they encountered our CAI course. Since their current instructors judged our future students to be still deficient in spelling skills, it seemed logical that we should prepare a spelling course for CAI that was not traditional in content, organization, or presentation.

A Linguistic Approach. As the basis for our course, we chose linguistic evidence about American English spelling, rather than the global impressions that speakers of the language have about its spelling. There were four main reasons for our choosing a linguistic approach to the teaching of spelling in this course; they are listed and explained here.

Rationale. The available empirical evidence shows that a linguistic approach is at least as effective as any other method of teaching spelling. Indeed, judging from the kinds and variety of spelling problems prevalent among our adult students, we predict that a linguistic approach will, in time, be shown to be more effective generally than other approaches. This prediction rests on some apparently contradictory characteristics of a linguistic approach: it is both realistic and optimistic; it is both analytical and synthetic; and it is a structured approach, but one without rigidity. For example, a linguistic approach begins by looking at what spelling really is: an attempt to represent speech sounds and words graphically, according to a standard usage. Since spelling is identified as an attempt to represent speech sounds, rather than as a means for doing it, there is an implicit assumption that the attempt may not always be fully successful. Beginning with a clear understanding of the nature of the spelling system can help to reduce a student's (and a teacher's!) hostility and impatience with the exceptions. In other words, if a student has some notion about how spelling irregularities come about, he is less likely to view them as senseless trouble spots, nearly impossible to master. Hence, he may attack spelling more optimistically than if he were told that it is a jumble of contradictions and inconsistencies occurring at random--but which he must learn.

A linguistic approach to spelling is analytical because instead of concentrating on an arbitrary string of letters that forms a certain word, it analyzes the identifying traits and locations of each component in the given word (and sometimes of the linguistic environment in which the word occurs.) For example,

we can linguistically classify a letter according to whether it is a vowel or a consonant; whether in a given word, it is voiced, voiceless, or silent; whether it has an initial, medial, or final position in its syllable; whether its syllable is accented or not; whether its syllable, if accented receives primary stress or less; whether it is preceded or followed by one or more vowels or by one or more consonants; the number of syllables in the word and their locations in relation to the syllable in which the letter of interest occurs; and which other letters occur in the word, as well as their auditory and spatial relations to the letter under scrutiny in the given word. Although the preceding may appear to verge on taxonomic farce, it isn't because it does much more than merely classify letters and show static relationships between them. The componential analysis of linguistics is a dynamic taxonomy; otherwise it would have no relevance for any part of language study.

Because a linguistic approach to spelling is ordered, it has a discernible structure; but because it grows out of language--a changing phenomenon--it also has to be flexible. It has to be able to accommodate modifications as the student recognizes a need for them. For instance, he may recognize stress as his crucial clue (i.e., analytical component) to spelling (e.g., *the white house* or *The White House*); he may recognize that the clue lies in the racial identity or the social class of the speaker (e.g., *the man* or *The Man*); or in the geographic location (e.g., *Storm damage was heavy in the Centre County area.* or *Storm damage was heavy in the center county area.*); or in the presence or absence of a pause (e.g., *Tuesday, weld.* or *Tuesday Weld*).

The more the student learns to identify significant differences, the more he benefits from a linguistic approach to spelling. For, by considering letters in terms of components like those listed above, students not only observe the presence or absence of a given component, but they begin to discern patterns and to generalize about necessary and sufficient conditions for particular occurrences of letters. Gradually, the analytic practices can lead to empirically generated rules, and ultimately to a sentient grasp of spelling.

Since other approaches have not succeeded in teaching spelling to our post-high school students, a linguistic approach is not likely to do less than the others have done. However, we repeat that a linguistic approach to spelling promises much more than other methods: It has a potential for bringing order out of chaos.

Behavioral objectives. A linguistic approach to spelling is compatible with reputable educational thought and practice. Today, much emphasis is placed on knowing what takes place at the behavioral level in a learning situation, rather than on philosophizing about what may be taking place at other, usually intangible, levels. That is, learning is planned and evaluated--or is supposed to be--with a behavioral frame of reference. This is particularly true for all CAI courses. Therefore, when we started planning this course, we prepared two lists of behavioral objectives because we had two entirely different aims for the course. One set includes the objectives we have for ourselves, as authors, exploring the capabilities of the instructional system. Since this set of objectives is a departure from the usual, it is discussed elsewhere.

The other set of objectives, however, centers on the students, as behavioral objectives normally do. This set deals with these major topics: entering behaviors, performance behaviors during and after instruction, and the criteria for those performances. For example, we assumed that our students would already be able to: read at an average adult rate; follow directions; type single words and symbols; and hold a pencil-like object. Therefore, we listed these as entering behaviors (i.e., prerequisite learnings and skills). Although these entering behaviors may seem obvious, failure to consider them precisely can lead to failure and disappointment, if not to disaster.

Evaluation criteria. Next, we designate what a student would have to do to show us on a pretest that he could spell sufficiently well to warrant his not taking our course. We decided that if he could identify the correct spelling of specified words in eight or more sentences located in 10 separate groups of five sentences each, he did not need the course. That is, we planned a 50 sentence test covering five common spelling error categories. Each category is presented in 10 different sentences, and each sentence has three spelling options. The five error categories we chose are these: final consonant doubling, ie-ei words, plural formation, final e words, and final y-to-i words. Thus, students who select eight or more correct spellings from 30 options in each of the five categories are excused from taking the course. Students who select fewer than eight correct spellings in any single category are judged deficient in spelling ability and they receive instruction in as many of the five categories as their pretest performances indicate they are deficient in. Precisely then, the behaviors stipulated for our pretest are the recognition

and selection of correctly spelled words. The acceptable (i.e., criterion) performance for those behaviors is set at eight out of 10 correct selections in five separate error categories (i.e., an 80% accuracy in each category).

For the posttest, we listed the same behavioral objectives. However, to decrease the possibility of lucky guessing, we decided to double the length of the test, covering the same five error categories with 20 sentences each. Consequently, in order to achieve the 80% criterion performance level, students have to identify 16 or more correct spellings from 60 options in each of the five categories. Students who do not attain an 80% accuracy in all five categories, are judged to still have spelling deficiencies in those error categories where they select fewer than 16 correct spellings.

For the five instructional portions of the course, which parallel the five error categories, we varied the behavioral objectives in accord with 1) the material being taught, and 2) the way in which we were then using the CRT to teach that material. For instance, in nearly every instructional portion, a student, in order to answer questions correctly, is required to perform each of the following cognitive operations: recognize elements and patterns (e.g., letters, words, shapes); differentiate among elements and/or patterns; identify and/or label elements and/or patterns; construct elements and/or patterns; relate elements to patterns and vice versa; infer, generalize, and/or formulate rules from elements and patterns.

In selecting these behaviors we were guided by the structure of a linguistic approach. So it is inevitable that a variety of mental operations would be required of our students. This inevitability, coupled with the assumed programing flexibility of the CRT, seems to make it possible for students to discover that spelling has more logic and order than they might have suspected from having performed mainly cognitive memory operations in the past.

In summary, just as linguistics focuses on language as it is actually used, the behavioral objectives imposed by linguistics and the CRT forced us to focus on what was actually happening in our course. Both linguistics and behavioral objectives provided empirical guidelines and checks for us as we worked; and empirical evidence of almost any kind is in accord with educational thought today. Thus, a linguistic approach to spelling, almost by definition, has to be compatible with reputable educational thought and practice--especially if the approach is used in a course built on behavioral objectives.

A patterned challenge. A linguistic approach offers older spelling students a new perspective on an old problem. The novelty of this approach for students accustomed to learning spelling mainly by rote is self-evident, and we have just discussed the variety of cognitive skills that the approach entails. But it might be appropriate to explain why it is especially important to recognize one reason why the novelty of this new and more demanding approach to spelling might be particularly important for our students.

By virtue of their being high school graduates who were accepted into educational programs at accredited institutions, our students must be regarded a underachievers as far as spelling is concerned. One of the most commonly given explanations for why students fail to achieve academically at a level commensurate with their intellectual ability is that they simply are not challenged by the learning tasks assigned to them. Hence, they usually fall into the habit of ignoring those tasks altogether or of doing them in the most desultory manner possible. When, as was probably the case with our underachievers, the assigners of the tasks provide little logical framework for the tasks and instead, often emphasize only arbitrary bases for them, it is not surprising that students fail to learn to spell.

A linguistic approach, on the other hand, because it presents spelling in quite a different perspective, and because it inherently demands more of the student, involves him intellectually in ways that spelling never did before. Furthermore, since he learns to detect and relate patterns himself, his learning experiences are almost certain to be more satisfying, both intellectually and emotionally, than memorization is. The very process of finding significant elements and relationships in spelling provides a challenge that few of our students are likely to associate with spelling. In short, by helping them see that spelling is, for the most part, logical, we challenge them to tease out the rationales behind apparent irregularities. In addition, this sort of concentration may help students learn the correct irregular spellings more effectively than has studying them in lists or in isolation.

The new perceptions fostered by the linguistic approach used in this course promise to provide strong bases and procedures for learning spelling. And perception has been shown to influence learning in many direct and indirect ways Hence, the apparent usefulness of a linguistic approach to spelling has important implications for underachieving adult students.

CAI-CRT Aspects

In our spelling course for post-high school students, the CAI-CRT aspects represent what we did in trying to understand and capitalize on the relevant and available capabilities of both of those technologies--and what we acquired through serendipity Ironically, our early thoughts about how to accomplish full use of our facilities were influenced by two disparate facts: a) CAI is often naively criticized as being little more than a very elaborate gimmick; and b) the CRT is a TV tube. What naive critics might be saying when they heard that the 1500 instructional system student stations used a TV screen was not hard to imagine. And what we imagined was very discouraging until we began to see possibilities in what might be called an "If-you-can't-beat-them,-join-them." approach. We began to consider the use of so-called gimmicks and certain television techniques as ways for capturing the attention and interest of our older students so that we could try to teach them spelling.

At that time, some of us had seen an earlier CAI installation use lines of print, static graphics, and moving graphics effectively and innovatively. But none of us had seen or read of anyone's using (or proposing to use) single letters or words as if they were themselves graphics. Nevertheless, the CRT's capacity for showing movement seemed particularly worth investigating--at least as an attention-getting technique The characteristics of our students and of our familiar subject indicated that a fresh approach would be desirable, so without knowing exactly how they would be used, the authors began to experiment with display techniques. By combining Coursewriter II command statements (e.g., pauses, display texts, display text inserts, etc) we soon found how to achieve attractive (in the literal sense of the word) displays on the screen. Gradually, as we worked with the 1510 screen, ideas and techniques began to build on themselves. Modifications seemed almost to suggest themselves as we considered techniques along with the subject matter of the five common spelling error topics we were teaching in the course. It was not very long before we realized that the novel effects we had started out using as interest-capturing gimmicks had very real advantages for teaching spelling Therefore, we started examining our course material in terms of the display techniques we had already developed, and asking ourselves what other techniques we could devise that would effectively present particular points that we wanted to make in our linguistic approach to our subject.

Some of the techniques that we developed are listed below together with their purposes and the effects they produced. Since the linguistic approach to spelling emphasizes componential analysis and pattern recognition, display techniques that highlight the components or patterns under discussion become intrinsic to both the text being presented and to the visual presentation medium.

Consequently, although we first anticipated capitalizing on the CRT's similarity to TV as an entertainment medium, we now regard that similarity as of minimal importance. The special display effects we use in teaching this course capitalize on the use of the medium as an instructional medium under the control of a computer.

Among the special display effects and techniques we used are the following:

1) The presenting of words on the screen in a spelled-out mode, that is, one letter at a time, not only because it is appropriate for a spelling program, but because it is an attention-getter.

2) The spelling out of a title by moving appropriate letters--one at a time--from outside of a screen and accumulating them correctly in the middle, and the animation of the then-formed words of the title for emphasis and as an attention-getter.

3) The systematic separation or merging of several root words and suffixes listed in a column to show the natures of the two parts, to demonstrate special spelling problems, and to identify points of juncture.

4) The flashing of right answers for emphasis and reinforcement.

5) The use of the top or bottom half of the multiplication sign (X) for an arrowhead without going beyond the 1500 system's dictionary.

<——————   ——————>

——————>   <——————

6) The building up of words in a column from the middle outward to demonstrate the doubling principle in spelling:

bb
a(bb)e
st(abbe)r
tt
o(tt)e
h(otte)r

7) The shortening of the command "PRESS SPACE BAR TO CONTINUE" to press (alternate coded letters) to allow the use of rows 30 and 31 for additional course instructions or directions.

8) The substitution at various times of "TYPE GO TO PROCEED" for "PRESS SPACE BAR TO CONTINUE" to increase slightly the student's sense of being meaningfully involved in his progress through the instructional part of a course.

9) The development of an internal quiz segment that allows a student multiple responses for one answer with a light pen. Feedback provides not only for a statement appropriate to an all-correct multiple response, but it lists the right and wrong choices in a partially correct multiple response.

10) The development of a quiz segment that allows a student multiple keyboard responses for one answer (either letters or words). The feedback provides for the showing of the right choices when all are correct. It also provides for the showing of right choices and wrong choices (indicated by hyphens) when the answer is only partially correct.

11) The "whiting" (alternate coding) of various letters within a word to emphasize patterns or critical areas.

12) The "whiting" (alternate coding) of key words in an instruction for emphasis.

13) The presentation of instructions on the screen in appropriate "phrase fragments" (one phrase under another) to increase ease of reading and comprehension and to create a symmetrically balanced screen image.

14) The use of animated visual effects to "imitate" certain auditory effects.

15) The development of a short program (including a sub-routine) which allows a student, in effect, to animate (that is, to join or separate) certain words on the screen by pressing the appropriate key a specified number of times.

16) The focusing of attention on a particular part of the screen by showing an alternate-coded pattern in the area where new material (e.g., a different question) will appear next. This technique is used when one part of the screen displays the same text throughout several frames, but another part of the screen displays a number of different pieces of text.

17) The presentation of evaluative feedback (yes, no) under individual words in a sentence, along with the retention of the positive evaluations until the student has answered all of the questions in that sentence correctly.

18) The use of relevant punctuation marks as indicators of negative evaluation when students persist in making the same error on internal quizzes.

In addition to these, we have prepared graphemic representations of the options (from which the student selects his answers) on the pretest and the posttest. These visual representations of sounds use symbols from the standard system dictionary as well as some symbols in a special graphics dictionary. They also use space significantly by raising and lowering symbols above the line of print and by leaving blank spaces within words. The main anticipated advantage of this sound representation system, developed by T. V. Barker of Lehigh University, is that every English letter in a spelling word has as its pronunciation counterpart a symbol that is easily recognizable as the alphabetic letter for which it stands. In the absence of audio facilities, this graphemic representation was chosen for students who might want to know how the three alternative spellings differed in pronunciation. This pronunciation section is programed as an optional branch the student can make on each test item if he wishes. Since it has not yet been tested with students, we can only estimate its usefulness. That estimate is, however, that it will be worth the time consumed in coding and inputting on-line the pronunciation symbols.

In the pretest and posttest sentences, students respond with a light pen. This has proved to be a very economical use of system time since it permits even CAI novices to be tested on a relatively large number of items in a very short time.

The content of the test sentences, it might be mentioned, was also influenced by the age and experience levels of our students. That is, we sought to make the test sentences as different from the usual illustrative spelling test sentences as we could without distracting students from the purpose of the test. That is, we constructed sentences that have a pseudo-literary flavor rather than the usual subject-verb-object sentences customarily used by spelling teachers. Since the pretest is the students' introduction to our course, it seemed important that he realize from the start that the CRT-CAI treatment of spelling was not "the same old stuff" simply shown on a TV screen.

Some Preliminary Implications

Although our course has not yet undergone extensive testing, it does not seem amiss to us to mention some of the probable implications that we have become especially aware of as we worked on this course.

1) The holistic approach which the CRT-CAI combination of media permits is probably a productive one, especially in the early stages of technological development.

2) The integration of the student needs, the subject matter structure, and the technological capacities of a CRT-CAI station appears to be particularly promising for remedial students and subjects *if* course authors examine how the unique qualities and capacities of each of these elements can be used to enhance and/or compensate each other in a learning situation.

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